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JOHN C. TRAUTWINE, JR., *Secretary*, 257 S. FOURTH STREET, PHILADELPHIA.

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## RAILROAD ORGANIZATION.

BY GEORGE T. SAMPSON, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, November 20, 1901.*]

RAILROAD organization is a subject on which new chapters may be written and required to describe the conditions of each new year, and I may say month, of the present times. The recent years have marked an epoch in railroad history when consolidation has been the rule in our country, when no scheme for uniting different companies seems too great to be considered and none too great to be consummated.

It appears to me as one of the noticeable results of the greater organizations, while in part it may perhaps be considered as a natural and proper growth and improvement in railroad methods, that while the duties of the great majority of men employed in railroad service continue on the same general lines, with responsibilities much the same as in years past, there is required of nearly all a better education and the performance of a greater amount of clerical work than was ever expected in the earlier years.

The larger organization requires an additional number of active workers in official and clerical positions not previously considered as necessary, numerically speaking, in the aggregate perhaps not especially different from the united numbers of those employed in the former separate companies which may have been combined, but all working in harmony, subject to but one highest in authority instead of working on many independent lines. It is because the one guiding mind at the head must in some way and manner be

*Manuscript received December 13, 1901.—Secretary, Ass'n of Eng. Socs.

informed of results attained and work performed by the lowest subordinate that this additional clerical work is required of all, and it is for the collection, compilation and tabulating of the great mass of facts and figures which come from the subordinates into proper shape for the intelligent consideration of the one at the head that the greater corporation needs to employ more clerical assistance and to establish departments with able men in charge in the intermediate positions which were not thought of in the earlier years. It is in these new departments, these intermediate positions, that the greater organizations of to-day become evident and distinctly different from our small organizations of twenty-five or thirty years ago.

A moment's consideration of the enormous volume of facts and figures which must pass daily from employe to officer, and from department to department, shows at a glance the need for correct and well-written reports from the source where information originates, and how worthless and futile a link in the chain of information needed is a verbal word of mouth report, which answered many, if not most, purposes in the earlier years of small mileage.

With this great and constantly increasing volume of facts and figures to be recorded and preserved grows the ever-increasing and greater need of properly arranging the relations between the departments and officers, so that the burden of the work may be intelligently distributed; so that all employes, while having sufficient to do, may not be overloaded, and so that the organization as a whole may move along in harmony and without vexation, delay and hindrance.

While I have stated above that it is necessary for the guiding mind at the head to be informed of the results attained by the subordinates, this should not be considered in any personal or individual sense, for it is only in the form of aggregate results, condensed and arranged in proper form for quick comprehension and ready reference, that they are of worth and value to the superior officer. It is in the compilation of reports, in the arrangement of information in fit shape to be forwarded and in the study of uses to be made of the results that many of the officers in the intermediate positions find their field of work, and the opportunities which tax their minds and energies, their patience, perseverance and ingenuity up to their full limit.

As it is by comparison with results and records of preceding days, months or years that one can realize and prove an advance or retrograde movement or change, so does it become necessary that, in the preparation of the condensed and aggregate results

above mentioned, a record should be made and left behind to trace the minutest thread of information which makes up the whole fabric. Such a record at the present time is made up and kept in order largely, I may almost say wholly, by the use of printed blank forms for reports, each so fully and completely worded as to cover all circumstances and combinations, with the blank spaces for information to be written in so ingeniously arranged that the employe charged with the duty of preparing the same has before him a guide which constantly reminds him of what is needed and expected from him, which plainly marks out and defines his work and which, when faithfully and honestly performed, furnishes results in the precise shape needed. Too much stress cannot be laid on the need and importance of having the best of printed blank forms in the systematic performance of railroad work requiring the services of many men, the results of whose reports are to be combined into aggregates with diverse classifications or distributions. Oral instructions of a superior officer about information to be gathered, and in the use of forms for reports, may be well and necessary at times, but, as in the case of a railroad organization, where many and most of its employes are at a distance from headquarters, where they cannot be spoken to except at long intervals, no better way can be devised for securing uniformity, for directing many minds into the same channel of thought and for keeping those minds in the beaten track.

This matter of blank forms, while a matter of detail, cannot be overestimated in its importance and in its far-reaching effects.

Think of one of our large railroad systems of to-day, with its thousands of miles, in comparison with one or a number of our smaller corporations of a few years ago! Take, for example, our railroad systems in New England, well known to us; while not operating or controlling as great a mileage as many of those in the Central, Southern and Western States, still sufficiently large in themselves to require as able talent and as good and systematic an organization as the best and largest.

To the north of our city, consider as a part of the present Boston and Maine system; its Eastern division main line extending 115 miles from Boston to Portland, made up of the former Eastern Railroad of Massachusetts, the Eastern Railroad of New Hampshire and the Portland, Saco and Portsmouth; its Western division main line, extending also 115 miles from Boston, also to Portland, was the original Boston and Maine Railroad; its Southern division main line, combined with the White Mountain division, extending from Boston to Woodsville, N. H., and points north, made up of

the former Boston and Lowell, the Lowell and Nashua, the Concord Railroad, the Boston, Concord and Montreal and the Northern Railroad. It also includes the Central Massachusetts Railroad. its Fitchburg division, made up of five or more original separate companies.

To the south, consider the companies which made up the former Old Colony Railroad system, now a part of the present New York, New Haven and Hartford Railroad.

Many, if not all, of the above-named companies, without considering other separate corporations which organized and constructed branch lines within the territory named not many years ago were operated independently, each with its own corps of officers and employes. A ride of a few hours was sufficient to go and return from one end of the line to the other. A short term of service was sufficient to familiarize each employe with the whole property. All knew each other, from the highest to the lowest. Questions were asked and answered with much informality. Information came from subordinate to superintendent, and from superintendent to president in short order; an interim of a few hours only elapsed oftentimes when matters first came up for attention and secured prompt decision. There was no intermediate between the superintendent and president, and not the slightest need for any. The problem of management was not then an intricate one, only such a one as could easily be kept in mind by the leading officers with the aid of but a comparatively simple system of records and accounts.

Let me here call your attention to plate No. 1, a chart or graphical representation of the various departments required for the operation of one of our larger corporations of to-day, an organization operating about 2000 miles of located railroad, with total tracks of about 4000 miles, employing now about 30,000 persons, with annual earnings of about $40,000,000. Notice that this chart shows the numbers employed in each of the departments; that out of a total of 30,000, those employed in the transportation department, the freight department and passenger department combined, who may be said to be the workers who earn the income, number 29,347 persons, or 98 per cent. of the whole. Another 1 per cent., or 304 persons, conduct the accounting department and keep the books, and the remaining departments, whose numbers combined amount to 294 persons, or the remaining 1 per cent., are entrusted with work which requires the direct disbursement of funds or the oversight of expenditures.

# RAILROAD ORGANIZATION,
Boston, Nov. 20th, 1901.

**CORPORATE OFFICERS.**

- Directors.
  - President.
  - Vice-Prest. of the Board.
  - Treasurer.
  - Secretary.

| Officer | Number of Employes. | DEPARTMENTS. | Head |
|---|---|---|---|
| | 16. | Treasury. | Treasuror. |
| | 304. | Accounting. | Comptroller. |
| | 15. | Pay Dept. | Paymaster. |
| | 49. | Purchasing. | Purchasing Agent. |
| First Vice-Prest. | 29,347 | Transportation. | General Manager. |
| Second Vice-Prest. | 87. | Freight. | Freight-Traffic Manager. |
| | 68. | Passenger. | Pass. Traffic Manager. |
| Third Vice-Prest. | 13. | Law, Real Estate, Taxes. | Attorney. |
| Fourth Vice-Prest. | 101. | Construction. | Chief Engineer. |
| | 30,000. | Total Employes. | |

- Treasury. — Treasuror.
  - Asst. "
  - Treasurer's Agents.
- Accounting. — Comptroller.
  - Auditor of Disbursements.
  - " " Pass. Receipts.
  - " " Freight "
  - Traveling Auditors, 9.
  - Ticket Receiver.
- Pay Dept. — Paymaster.
  - Asst. "
- Purchasing. — Purchasing Agent.
  - Stationer.
  - Storekeeper.
- Transportation. — General Manager.
  - Gen'l Superintendent. First District.
    - Div. Superintendents, 5.
      - Asst. Superintendent.
      - Train Despatcher.
      - Roadmaster.
      - Bridge Supervisor.
      - Conductors and Trainmen.
      - Station Agents.
    - Signal Engineer.
  - Gen'l Superintendent. Second District.
    - Div. Superintendents, 8 — Do. Do.
    - Signal Engineer.
  - Gen'l Superintendent. Third District.
    - Div. Superintendents, 5. — Do. Do.
    - Signal Engineer.
  - Supt. Motive Power.
    - Gen'l Master Mechanic—Div. Master Mechanics, 8. Round House Foremen.
    - Master Car Builder. Shop Foremen, 7. Car Inspectors.
  - Supt. Electrical Dept.
  - " Sleeping Cars.
  - " of Buildings. — Asst. Supt. of Buildings.
  - Car Accountant.
  - Fuel Agent.
  - Supt. of Telegraph.
  - Advertising Agent.
- Freight. — Freight-Traffic Manager.
  - Gen'l Freight Agent.
  - Asst. " "
  - Foreign " "
  - Special " "
- Passenger. — Pass. Traffic Manager.
  - Gen'l Pass. Agent.
  - Asst. " "
  - Gen'l Ticket "
  - " Baggage"
  - Asst. " "
  - Express Agent.
- Law, Real Estate, Taxes. — Attorney.
  - Real Estate Agent.
  - Rent Agent.
  - Asst. Rent Agent.
  - Claims Attorney.
  - Local Attorneys.
  - Claim Agents.
- Construction. — Chief Engineer.
  - District Engineer.
    - Division Engineers, 3.
    - Special Resident Engineers, 4.
  - District Engineer.
    - Division Engineers, 3.
    - Special Resident Engineers, 4.
  - Bridge Engineer.

# RAILROAD ORGANIZATION.

CORPORATE OFFICERS.

- Directors.
  - President.
    - Chairman of Board.
    - Corporation Clerk.
    - Comptroller & Gen'l Auditor. Financial and Accounting.
      - Treasurer.
        - Paymaster.
        - Asst. Paymaster.
      - Asst. Gen'l Auditor.
      - Chief Traveling Auditor.
        - (6) Traveling Auditors.
      - Auditor Passenger Accounts.
      - Auditor Freight Accounts.
    - 1st V. P. & Gen'l Manager. Operating.
      - Asst. General Manager.
        - Div. Superintendents (10).
          - Roadmasters.
          - Bridge Supervisors.
        - Maintenance of Way.
      - Gen'l Superintendent.
        - Operation.
        - Div. Superintendents (10).
          - Asst. Superintendents.
          - Conductors & Trainmen.
          - Station Agents.
          - Train Masters.
          - Train Despatchers.
      - Chief Engineer.
        - Asst. Chief Engineers (2).
        - Bridge Engineer.
        - Division Engineers (6).
      - Supt. Motive Power.
        - Asst. S. M. P.
        - Master Mechanics (8).
      - Master Car Builder.
      - Supt. of Signals.
      - Purchasing Agent.
      - Stationer.
      - Chief Electrician.
      - Supt. Car Service.
      - Fuel Agent.
      - Supt. of Telegraph.
      - Real Estate Agent.
      - Attorney.
        - Asst. Attorney.
        - Gen'l Claim Agent.
        - Claim Agents (6).
    - 2d V. P. & Gen'l Manager. Traffic.
      - Freight Traffic Manager.
        - Asst. General Freight Agent.
        - General Agent.
        - Trav. Freight Agents (7).
        - Div. Freight Agent.
        - Canadian Freight Agent.
      - Export Freight Traffic Manager.
        - Foreign Freight Agent.
      - Gen'l Passenger & Ticket Agent.
        - Asst. G. P. & T. Agents (3).
        - Gen'l Baggage Agent.
        - N. E. Passenger Agent.
        - General Western Pass'r Agent.
        - Division Passenger Agents (3).
        - Canadian Passenger Agents (2).
        - Traveling Passenger Agents (2).
      - Superintendent of Elevators.

Also note plate No. 2, showing an organization operating about 2250 miles of located railroad, with total tracks of about 4000 miles, employing now about 24,000 persons, with annual earnings of about $30,000,000.

On this chart, plate No. 1, I have attempted to show the relation existing between the highest and those officials at the lower end of the list, which may be spoken of as subdivisions of departments, in which a considerable number may be employed and where the official at the head of the same, with well-defined title and duties, is charged with the execution of work controlling the receipt or disbursements of funds or material for which he may be required to render an account and held responsible for the accuracy of the same. It shows how these lowest officers are related and connected to the highest through the intermediate officers mentioned in the preceding pages.

From it, to illustrate an idea which I have tried to make clear in the preceding pages, I may take the office of division superintendent, standing to-day in its relation to the operation and maintenance of road much the same as one typical of the superintendent of the small original company of former years, it no longer has intimate and close relations with the president, the highest officer and controlling mind. Reports of operation from his office, except in cases where comparisons are desired, united perhaps with other reports from other like officers in their passage through intermediate departments, finally reach the top divested in large manner, and I may say entirely, of their individuality. It is to-day a part of the duty of the division superintendent to care for the interests of the company, the public and the individual in the district traversed by the mileage under his control; not only to tend and look out for industries already created, but to encourage and develop new undertakings and negotiate and arrange, as far as operation is concerned, contracts and agreements for the same.

With the railroad company, as in most other corporations, it is manifestly right that only the president and a comparatively small number of the higher officers duly authorized should, in the matter of contracts, sign for and bind the company, and so we see, from a study of the plate in this one instance, how the contract goes from one to the other through the intermediate officers, subject to revision if necessary; how the time is consumed when it passes—not singly, but as one of many similar matters combined with a large volume of other business—from one to the other, and we realize the difference from the good old way; we see the cause for the time consumed, and understand how slowly large bodies have to move.

The foregoing pages, somewhat digressive in their wording, have perhaps clearly presented the contrast between the past and the present, between the smaller and the larger.

It is superfluous to here give reasons for the existence of the corporation. The officers in the organization, as agents of the owners, the stockholders, take it for granted that the prime object in their view is the profit to be derived for its owners from the performance of its duties in serving the public according to law and its charter rights as construed in a broad-minded, public-spirited and economical way.

As money-making concerns the railroads have surpassed all dreams entertained by their first advocates and promoters. From the start, the study has been absorbing to determine how to best handle the concern, but as years have rolled on certain principles and methods have been evolved and may now be considered as well recognized and defined in the railroad world. In our own country the requirements of the State railroad commissions and of the national Interstate Commerce Commission have been most prominent and effective in bringing about a uniform system of records and accounts. It is perhaps too much to say that all of our railroad organizations arrive at results in precisely the same way, but it is safe to say that all in the United States do now report the results of their operations on precisely the same forms, and that it is therefore a necessity for them to organize and work on very nearly similar lines in order to furnish results in the forms desired.

In considering this subject the question at first arose in my mind whether to attempt to describe an organization as it is now arranged and operated, or whether to attempt to improve upon it, to originate and create something ideal and perfect. A short consideration of the question only was necessary. Our predecessors in the United States have not worked in vain, and we may be justified in indulging in a little vanity and pride when we consider the results here obtained as compared with those of the other nations and of all other parts of the world. In many respects we have the best,—surely so from an economic standpoint. When I indulge in the boast of saying that we in the United States have the best railroad organizations in the world, let it not be thought that I for one moment imagine that we have reached perfection. It is far from my mind to attempt to create such an impression, and I may go further and say squarely that the attainment of perfection is impossible now, as it always will be. It is only possible for the railroad employe and officer to keep always in his mind an idea or standard of that which is best, and honestly strive to achieve and

perform his work, within the lines laid down in a loyal spirit, as nearly up to his standard as he may be able. Working as an individual officer, one can only advance as far and as fast as co-operation can be secured with other officers or departments, and from a certain standpoint the progress and success of a large corporation can only be rated as the average success of the many minds employed on its problems as fast as they can be harmonized and made to work in unison. That which is oftentimes looked upon as a most wise move in one department can only be considered with doubt and uncertainty by another.

While it is necessary for the railroad employe to perform his work in established ruts or lines, according to rules and standards, still a progressive company must live close up to the demands of its times and regulate and change its rules and standards to suit. As too frequent changes with many men interested can only lead to confusion it is, for the sake of uniformity, often expedient to for a time adhere to a standard inferior to the best, and long enough to work out the changes needed at convenient opportunities without trouble. Here, again, we see the possibility of attainment of only average results, and so long as it fails to attain that which is perfect and best, so long will the corporation organization be a subject of criticism, both within its own ranks and without. It is the wise and successful officer, who works best for the interest of his company, who can best weigh these acknowledged defects without nervousness and ill temper; who can discriminate between the superficial and the deep-rooted troubles, and change and grade up his department methods at the proper time.

As nowhere in other countries have like economic results been achieved, and since as a whole we think that we have the best, let me be satisfied to describe one of the best as it now is, trusting that those who follow after in the service will rise equal to the occasion, continue a progressive policy and make the improvements needed as fast as the good of the service demands.

In making a description a question again arises as to where to make a start. Shall it be with the highest or the lowest? As one of a profession entrusted with construction works it takes but little time to decide that we must have a foundation to build upon, that the foundation must be built at the beginning, and to see where that beginning is.

It is rather outside the scope of this paper to consider the first preliminaries,—the issue of the charter. Such matters are largely of the past rather than the present. We will assume that the life of the railroad begins with the men entrusted with the selection of the

ground or route over which it is located, and we pretend to know all about the craft or set of men who were first charged with that duty.

While in the earliest and first years of the railroads, when a start was made, a chief engineer and his assistants were appointed at about the same time as the treasurer and secretary and its first officers, yet on the completion of the line and commencement of operation oftentimes it was considered that there was no longer need for the civil engineer, and his services as an engineer were dispensed with in much the same way as the large part of the army of laborers and mechanics who had been employed. On most of our New England railroads, except in certain cases where the engineer showed special ability for organization and for the operating work, and excepting those roads of considerable mileage, which found it profitable to continue the construction of new extensions and branch lines, there followed a time for a generation or more when the civil engineer, the man who made large expenditures, seemed to be left out of the calculation in the sense of being considered as a necessary part of the regular organization. He was only employed for special work, in a temporary way, as long as the special work lasted; but as the volume of traffic and resulting income increased, as the road outgrew its facilities as at first provided, it became necessary to turn again to the civil engineer as the man best suited by education and training to successfully solve and plan out the large works arising and to economically direct the large expenditures necessary.

At the present time, by referring to our chart, plate No. 1, we note that it is necessary to have a vice-president, charged with the special care and oversight of construction work, and subject to him a chief engineer, with a bridge engineer, district engineers, division engineers and special assistant engineers for such large special works as might prove too onerous for the regular engineer of a division.

In a paper of this kind it is unnecessary to attempt to detail the duties of the higher officers. The name of the department under their direction suggests in a general way the nature of their work. The chart shows how the several departments are related. When we consider the 2000 miles and the extent of the territory traversed, the volume of new work that must arise, the relations to be cultivated and maintained with the public and outside interests pertaining to this work, the number of subordinates whose efforts are to be supervised and directed, we realize that their time and attention must be occupied up to the full limits.

In the construction department, which is charged with the duty of building, and to a considerable extent maintaining, the right of way, yards, roadbed, tracks, bridges, buildings, water stations, etc., we see it as the privilege and duty of the officer at the head of it to determine upon and direct the preparation of standard drawings and specifications for all materials and mechanical parts which may enter into the same, so far as they can be made to serve the purpose, to inform all the departments interested and his subordinates of these standards; and having decided upon work to be undertaken and having assigned the same among his subordinates, meaning particularly the district engineer and the division engineers under him, we come to an officer in the division engineer who may be said to have work that is to a great extent a regular routine. With certain mileage, or part of the system, assigned to his care, it is his duty, with the assistance of the force under him, to keep thoroughly informed of all the characteristics of his division,—its grades and alignments; its mileage and stations; its right of way, fences and land lines; its record of location and title deeds of land owned; its highway and private crossings; its yards and tracks, with the various patterns of rails, frogs and switches used in the same; to a considerable extent its interlocking systems, signals and buildings; its bridges, with the age, length, strength, kind, condition and pattern of each; its water stations, with the locations and sizes of tanks, pipe lines and water cranes, together with the sources of supply and their capacity. He is expected to have information on all these subjects ready for use at all times on short notice; to keep plans and records perfected and correctly up to date.

In ascertaining and maintaining the maximum clearance section of his line he has a work of no small importance, requiring a critical and painstaking accuracy in inspection and measurements, these to be corrected for rail elevations and curve ordinates; and in making answers to frequent inquiries about the possible movement of rolling stock of unusual size from foreign lines arriving at junction stations.

Added to the work above named, which is largely a matter of maintenance, comes that which is necessary in planning and estimating for additions or changes in arranging for new construction, the specifications, statements of quantities and schedules of materials. When, for work to be performed by company employes, the material needed is to be purchased through the purchasing agent and supply department, requisitions must be written on proper blank forms, so specifying each item in descriptive wording known to the trade that the correct and proper article will be surely procured and

delivered by the party who may receive from the purchasing agent the order to supply the goods.

When we consider that oftentimes and generally the purchasing agent and supply department is at a long distance and miles away from the official who writes the requisition, that conversation and exchange of ideas is oftentimes out of the question, we realize the importance of precision and of a proper wording in writing requisitions. It is the secret of success for many a corporation man. It proves the need of a man trained in the service, who can so only obtain the ready fund of knowledge and wide information about terms and common customs in use among dealers and of classes and qualities of materials available in the markets.

In the matter of accounts approved bills for labor or materials (for freight charges or train expense) must be forwarded to officers next above in rank, with notations on the same clearly stating their distribution under headings or titles of accounts furnished by the accounting department.

From the chart we note the department of law, real estate and taxes, and the corps of officials needed for its work. As the corporation is a creation of the law, so must its administration be conducted according to law, and the necessity is apparent for the employment of those thoroughly versed in its tenets. All other departments need advice and information about the law's requirements and restrictions. All kinds of legal talent are represented in the department, as counselors or advocates in civil or criminal proceedings, or as conveyancers and real estate lawyers.

The corporation pays taxes as found correct, both its State taxes as a corporation as well as the local taxes assessed on property in towns and cities. By force of circumstances largely, rather than from choice, the company is possessed of land and buildings to be cared for and made remunerative; property outside of that which is absolutely necessary for the operation and maintenance of the railroad, and to properly execute its undertakings new purchases are frequent. The real estate and rent agents prove quite as necessary for the company as for any large individual property owner, and they fill an important place in the organization.

The railroad corporation is a target for all kinds of claimants. Its weak and vulnerable points of attack are always exposed to view. The claims presented are of all kinds, honest and dishonest, just and unjust, of both large and small amounts, arising from all imaginable and possible causes. Prominent among them are personal injury cases, the lost or damaged freight or baggage cases and fire damages.

It requires a force of trained attorneys and agents to consider and weigh the evidence in these cases, to sift the false from the true, to decide which shall be settled out of court, which shall stand the chances of trial and to prepare a case for trial, as well as to conduct it.

The passenger department, in common with the freight department, is distinctly one of the money earners, its important expenditures being practically only those necessary to support its employes in its daily routine, to advertise its line in an enterprising, attractive and progressive manner and to pay its bills for printing. While charged with the duty of maintaining an active and constant lookout for new passenger business, of devising ways and means to secure and accommodate it when obtained, it is also its chief duty to fix the rate or price for passenger travel, to maintain its rates and sell its service at a lawful and reasonable price; and originate and continue in its proper channels the daily system of collection of income, so essential for the life of the corporation and without which it cannot long endure.

In most of the companies in the New England States the annual passenger and freight earnings seem to be about equal in gross amount of money earned. The passenger traffic ordinarily looked upon as the most profitable, since the passenger moves himself in and out of the train (unlike the bulky ton of freight, with its attendant expense of freight handlers, houses and terminals), also proves the more elusive, inasmuch as the passenger moving himself, also thinking and acting for himself, is always on the watch seeking for a new route or a new combination of rates and lesser fare.

Reference to the chart of our sample system shows at the head of the passenger department a passenger traffic manager, and he assisted by one or more general passenger agents, their number depending much on local peculiarities of the line or its traffic; a general ticket agent, a general baggage agent and an express agent. The title of each carries with it a pretty good suggestion and definition of the duties of each.

Without attempting to be too comprehensive in the description of the duties of these officers, suppose we take up as a single subject the consideration of tickets, their issue, sale and collection. Think if you will of the hundreds of passenger stations on a modern system. Consider for a moment the multitude of combinations possible and the large figures resulting if it should be found necessary to furnish a considerable number of tickets for travel from any one station to all others of the system, to say nothing of through tickets to stations on connecting lines. Suppose one single new

station should be added to the system, would it not be quite an undertaking and expense to simply get in order and furnish proof for the printer, not only in the preparation of the tickets themselves, but in the revision of the tariff sheets of rates, in the revision of mileage tables, in the preparation of time tables and folders and so forth?

Can you wonder that corporation officers and the passenger traffic managers hesitate about recommending or granting the petitions of real estate operators and of the inhabitants of sparsely settled districts for the establishment of new stations, the income of which for years would not probably pay the cost of heating and lighting and the salary of an agent, to say nothing of the cost of maintenance? But suppose a favorable decision is reached for the establishment of a new station, or for an issue of tickets for a new route over a connecting line, and the passenger traffic manager directs the general passenger agent to arrange for it. The general passenger agent at once directs the general ticket agent to prepare the issue, determining the price at which the tickets shall be sold; arranges with connecting lines the percentages for the division of receipts, notifies all station agents and passenger conductors of the issue and prices and reports to the auditor of passenger receipts all the details of arrangements so made.

The tickets, having been printed and made ready by the general ticket agent, are by him sent to the station agents for sale, a carefully prepared record having been made of the numbers delivered to each agent and that record also forwarded to the auditor of passenger receipts.

The station agent, on making sales of tickets, sends daily cash remittances to the treasurer, and monthly reports of all tickets sold and prices for same, and tickets remaining unsold, to the auditor of passenger receipts, taking credit for cash paid out for cash rebate checks redeemed. The passenger conductor on his train, having been previously notified of the lawful issue of tickets, recognizes all such when offered by the passenger, collects a cash fare when no ticket is forthcoming, issues to the passenger a special cash rebate check (in such case retaining for himself a duplicate of the same) and daily remits to the treasurer all moneys so received; and forwards to the auditor of passenger receipts all tickets collected and duplicates of cash rebate checks issued, with reports covering the same on proper blank forms.

Following the routine outlined above, the income and earnings of the passenger department are traced to the treasury department,

and the record and account of sales are so finally deposited with the accounting department.

The advertising part of the passenger department constitutes no small part of the work in each general passenger agent's office, and while large sums are annually spent in such work, still, like all business which has a healthy growth, there is no doubt of the need for the expenditure. The public wishes to know and needs to know all of the scenic and historic attractions on the line, and numerous pamphlets and books are issued descriptive of summer resorts and places of interest. The public needs to have traveling made easy; needs to have always before them and handy for ready reference leaflets and pocket time tables showing the time for arrival and departure of trains. The issue of these pocket time tables, kept up to date and correct for all changes of trains, for one of our modern corporations annually reaches a number of million copies. So much I may say and more for the passenger department without more than mention of special business which covers the question of arranging prices and accommodations for special excursions, private cars, theatrical troupes, and so forth, which are oftentimes moved over the road on a special time schedule arranged with the transportation department.

The freight department, one of the money earners, starting originally with the simple proposition to arrange for hauling freight short distances between local points on a single system, has grown to an organization equipped for a volume of business enormous in its proportions and far-reaching in its relations. Under contracts and relations now existing between connecting railroads, it is possible to ship property on a single through bill of lading across the continent, from ocean to ocean, and I may perhaps add across the ocean also. As our railroads in New England, with a terminal at the exporting city of Boston, transport enormous quantities of grain, provisions and other commodities coming from Western States and destined for European ports, their relations are of necessity closely identified with the steamship lines plying to and from the port. It is, however, rather beyond the scope of this paper to attempt to describe these relations further than to say that our Boston railroads find it necessary to appoint a foreign freight agent, who, subject to the orders of the freight traffic manager, is required to keep in communication with shippers and agents at interior points; also with merchants, shippers and steamship agents in our terminal city and abroad. While always looking out for the company's interests in general, it is his particular duty to quote rates, to book and engage space in the steamship, to arrange and time rail

shipments so as to properly connect with the vessels, as well as to arrange for lighters if necessary to transfer goods from cars to lighter and from lighter to steamship.

Special freight agents and traveling freight agents are the solicitors for freight to be shipped to competitive points, as well as for new business, paying proper attention to freight claim matters.

The making of freight rates is the duty of the freight traffic manager, and of the general freight agent, under supervision of the former. The division and percentage of through rates is also arranged by these officers. When rates are decided upon, notices of the same in proper form are sent to the accounting department and to all agents at all stations.

The ordinary routine business of the freight department is as follows: A person desirous of forwarding goods presents with the property to any railroad agent an original and duplicate form of shipping receipt, on which the goods are enumerated and described. These are, if found correct, signed by the agent and the original given to the shipper as a receipt and evidence of contract. The duplicate is held by the agent as a forwarding order, and used by him in checking the goods into the proper car, and from it the way bill is written with charges at tariff rates. The agent keeps a press tissue copy of all way bills issued. If made out in season, way bills go forward by the train which carries the goods in custody of the freight conductor.

All agents who write a way bill send a copy of the same to the accounting department, where it is checked as to rates and proportions. In cases of through shipments to distant points over connecting lines, owing to pressure of business and to a desire to make prompt delivery, cars are often forwarded before the way bill percentages are figured out and written in on the way bills. In such cases the way bills are sent by United States mail to the junction point at the first connection with a foreign road via which the goods are routed, where the respective agents take the way bills into account, the receiving agent paying to the delivering agent the revenue earned up to that junction station. A terminal road and station pays all accrued charges, and is reimbursed by collection from the consignee. Settlements with connecting roads at junction stations, or with consignees, may be made daily, weekly or monthly, as agreed upon. Freight charges are a lien on the goods, and usually collections are made when goods are delivered; but where regular customers are known to be financially all right credit arrangements are not uncommon.

When a shipment reaches a terminal, it is the first duty of the terminal agent to audit the way bill and detect errors either in rates or extensions, as well as to check up the quantity and condition of the goods.

Notwithstanding all systems and care used to detect and avoid errors, they will creep in; and, with cases of accident and injury to goods, it becomes necessary to employ a freight claim agent with a clerical force under him larger than that which is employed to originate and direct the regular work of the general freight agent's office. Claim cases per year count up into the tens of thousands. It is the duty of this office to meet the claimants, to collect all the evidence bearing upon each case and to adjust the same if possible.

In case of through billing, where loss or error occurs at a distant point on a foreign road, it often occurs that the local or terminal road settles with and pays the claimant and collects from the foreign road at fault, being first convinced that the foreign road acknowledges the error and will pay.

This matter of claims is of such magnitude and importance as to cause the organization of the Freight Claim Association, in which the freight claim agents of each represent the interests of their respective roads. Its object is the prompt and equitable settlement of freight claims with claimants and between carriers. It has become an interstate association, including 206 railroads as its members, representing 167,091 miles in the United States, Canada and Mexico and 5000 miles of water lines, combining 90 per cent. of all transportation lines in North America. Each railroad designates its representative in this association, which formulates and publishes rules for the uniform guidance of each freight claim agent's office.

Freight receipts are forwarded to the treasurer and accounted for to the accounting department in much the same way as has been previously explained for the passenger department, and statements above made about duplicate way bills show how the accounting department can check the accuracy of agents' reports and remittances.

In the transportation department the officer who may be said to be most closely informed in detail of the movement of trains is the division superintendent, acting under the supervision and orders from a general superintendent. He is expected to keep the wheels turning in an orderly manner over the mileage entrusted to his care, and to promptly restore order in each case should disorder arise. He is entrusted with the duty of preparing time

tables, of seeing that trains are safely handled in accordance with the same, subject to the standard rules and regulations, and of enforcing the observance of the rules among the employes. Every employe while on duty connected with trains, on any division of a road, is under the authority and must conform to the orders of the superintendent of that division.

Standard time must be maintained over the division. The preparation of a time table requires much thought and care on the part of the division superintendent, with an intimate and detailed knowledge of the stations and of all the physical characteristics of the line,—its grades and alignment, its water stations, its side track facilities, etc. No detail can be overlooked or considered unimportant, and when once blocked out and decided upon the proof from the printer must be carefully scrutinized and all errors eliminated before its issue.

As the division superintendent is entrusted with the safe conduct of the trains, so there is afforded to him, as a means to that end, full control not only of the trains and men employed on them, but also of the right of way, roadbed and its structures and all employed in their maintenance. In the performance of his duties he is assisted often by an assistant superintendent on lines where business is heavy, and always by a train dispatcher, a roadmaster and a bridge supervisor. The conductors and other trainmen and station agents look to the division superintendent for their instructions in the care of company property, and all matters other than those of income and accounts.

The chief train dispatcher has direct charge, under the superintendent, of the movements of all trains. He keeps posted about the volume of traffic, orders out the motive power as needed and directs car movements accordingly. The trick dispatcher works eight-hour tricks. With the aid of the telegraph he keeps in mind where all trains are, issues orders needed and makes the entries on the train sheet showing their movements. Operators at way stations report trains to him, and receive and deliver orders to trainmen.

The roadmaster reports to and receives instructions from the superintendent. He has charge of the maintenance of the roadbed, culverts, masonry, tracks, sidings, yards, depot grounds, road crossings and fences, and is responsible for the safe keeping of all material and supplies used in such work. He has full control and authority over section foremen, trackmen, crossing gatemen and flagmen, laborers and construction trains while at work. It is his duty to report to the superintendent the time of all employes under

him on proper forms for entry on payrolls, properly distributing their time to the various works in progress for the information of the accounting department, and in similar manner make report and distribution of all materials used. Materials, supplies and tools are to be carefully inspected when first received and checked by the invoice, making prompt report in case of discrepancies.

The length of line which may be assigned to the care of the roadmaster will vary considerably, according to local conditions and peculiarities, but in a general offhand way it may be talked of at about 150 miles or less. This mileage is divided into sections of about 3 to 6 miles each, and each section given its number, with its limits clearly defined. Each section has its section foreman, and a sufficient number of men to properly perform the necessary work, varying according to the time of year, a rate which averages about one man per mile for the system through the spring months and early part of summer, when new ties and rail ought to be put into track; about three-quarters man per mile, after the allotted number of ties have been placed, through the late summer and fall, and about one-half man per mile through the greater part of the winter, excepting when a special extra force may be hired for cleaning snow and ice as occasion requires.

Much depends on the watchful care and faithfulness of the section men, and as a rule they are to be depended upon in any emergency, and are entirely loyal to the road where they are employed. They are the foundation of all good railroading, for it is of the first importance to have the roadbed and track in first-rate order, and it is their duty to make and keep it so. The section foreman, or one of his men detailed for the purpose, is required to examine the full length of his section every morning. He is also expected to patrol the section, both by day and night, during heavy storms or violent winds, and to especially watch all points where obstructions are liable. He also must keep informed of the time tables and the rules for the movements of trains; must keep well supplied with torpedoes, flags, lanterns and all stop signals, and be possessed of intelligence to properly use the same. Many more of his duties might be enumerated, but lack of time and space forbid. The section foreman should forward to the roadmaster regular weekly and monthly reports of labor and material, with the expenses properly distributed on proper forms.

The bridge supervisor reports to and receives instructions from the division superintendent. His work on the maintenance and repairs of bridges brings him into close relations with the engineering department, requiring frequent conference as to the

best methods to be employed or plans to be adopted. He is required to make frequent inspections and keep informed in detail of the condition of all structures under his care. Large quantities of lumber and other material are used under his direction. It is his duty to inspect and check up material by the invoices, to report discrepancies or mark his approval on the bills if found correct as to quality and quantity. Reports showing distribution of expense for material and labor are required also in his case. He is also required to be familiar with and obedient to the rules governing trains, trainmen and other classes of employes, so far as they relate to the proper discharge of his duties. He needs to be a thorough mechanic, ingenious and quick to act in emergency; of sound judgment as to the strength of materials, industrious and energetic.

Conductors, in common with locomotive engineers, on both passenger, freight and work trains, are required to handle their trains according to the time tables and the orders issued by the superintendent. It is the duty of the conductors to make record of and to report to the superintendent the numbers and initials of cars as moved in their trains, whether loaded or empty; and at stations named in the time tables as registry stations to make entry in books provided showing the time of arrival and departure of trains, the numbers of locomotive and cars and the name of engineer and conductor. Conductors must also report car initials and numbers as moved in their trains, and state whether loaded or empty, in the same manner as agents.

Station agents report to and receive orders from the division superintendent, and also obey orders and instructions issued by the officers of other departments with which they have business relations. They also make report to the manager of the New England Car Service Association. At a small station the agent acts also as telegraph operator, while the larger and important stations have a freight agent, a ticket agent and operators also. Agents are responsible for the general condition of the buildings, yards and company property at their station, and look out for the company's interests in their city or town. It is a part of their duty to see that side tracks, switches, signals and lights at their station are kept in order; to see that cars are properly placed for loading and unloading; to see that loads placed in freight cars are such as to have them move generally in a homeward direction; to see that cars before loading are in proper order to receive freight; that loads on open cars are within proper limits, and that cars are not overloaded; and in cases where freight is found to be damaged or short of quantity as billed, to make a complete record of all conditions and cir-

cumstances. Proper way bills must always accompany all freight packages or cars. The agent is required to handle the United States mail according to fixed rules. Each agent sends daily reports, by telegraph if possible, to the car accountant, showing freight cars wanted, on hand and to spare. He also sends daily reports on proper blank forms showing car initials and numbers in detail of all arrivals and departures by train numbers and of cars remaining at his station. From the information so obtained, the car accountant is enabled to properly distribute cars of the proper kind to the stations where most urgently needed with the minimum length of haul, and also to direct the movement of freight cars in a homeward direction.

The car accountant is also thus enabled to keep an account of all cars and of the mileage of both home and foreign cars. Based on these records of mileage kept by the car accountant, settlements are made with foreign roads for the use of cars at the rate of one-half cent per mile. For the settlement of demurrage charges, station agents are also required to send daily reports to the New England Car Association, stating in detail car numbers and initials, dates and time of day they are placed for either loading or unloading. The demurrage rule is that for loading or unloading freight cars consignees or shippers are allowed ninety-six hours after the car is placed in an accessible position, and if the consignee or shipper requires more time he is required to pay for the detention at the rate of one dollar per car per day.

The New England Car Association, on account of demurrage questions, handles reports of about 1,800,000 separate freight cars per year for nine railroads in five of the New England States. It is supported by these nine companies. As a matter of interest I may here state that it is ascertained that the average railroad detention on all of the above-named cars is 35-100 day, and 1 65-100 days for delays on account of consignee or shipper. About 3 per cent. of the total number of cars pay demurrage, and this percentage has been about uniform since the association was established in 1894.

The machinery department, as a part of the transportation department, is under the supervision of the superintendent of motive power, and subordinate to him are the general master mechanic in charge of locomotives and shops and the master car builder.

The general master mechanic supervises the division master mechanics and roundhouse foremen. The master car builder supervises the car shop foremen and car inspectors.

As a rule it may be stated that but few roads now build their own rolling stock, finding it more economical to purchase and have them built by contract with outside firms, and finding their shop facilities generally kept busy up to their capacity by their repair work. The extent and importance of repairs on rolling stock can be realized when I state that it is generally allowed by railroad men that about 10 per cent. of the entire number of locomotives are in the shops for repairs constantly.

Shops for locomotive and car repairs of considerable extent are located at points most favorable. Minor and less important repairs on locomotives are made at the roundhouses; such as can be made without placing them out of service. Car inspectors' shops and outfits are maintained at terminals and junction stations with foreign roads.

Locomotives seldom leave the rails of the home road. At junction stations all cars arriving from foreign roads must pass under the eye of the car inspector. As to size of the car or its load, it must be within the advertised clearance limits; and it also must be in safe and secure condition in all its details, and not be overloaded beyond its rated capacity; otherwise the car inspector orders it to be sidetracked and the home road refuses to accept and handle it until its defects are remedied by the foreign road if it is a car defect, or by the shipper or consignee at times if improperly loaded in a way for which they are responsible. Car inspectors make repairs of injuries or broken parts when such can be made by the replacement of ready-made standard parts, of which they keep a stock on hand. In case more extensive repairs are needed cars are sent to the extensive main repair shops.

Speaking in a general way, it may be said that shops for locomotive construction or repairs consist of the blacksmith shop, a foundry at times, the machine shop and the erecting shop; and for car work the blacksmith shop, the wood-working shop, the erecting shop and the paint shop. Each of these shops has its foreman.

Division master mechanics and shop foremen need to employ considerable office or clerical forces. In these offices the payrolls and requisitions for material are made out, and thence to the superior officers for approval and through the usual channels hereinbefore mentioned.

Records and accounts of considerable interest are kept in this department, among which may be mentioned the method of guarantee and mileage account kept for the purchase of wheels, in order to make sure that the utmost care shall be taken at all times in their manufacture.

Wheels of all kinds when purchased are numbered and recorded with a full description, and a record made of the dates when each may be put under cars or engines. Shop foremen, roundhouse foremen and car inspectors have blank forms for reporting all wheels taken out or put in.

Wheels are bought under various guarantees. Chilled cast iron are considered good for about 60,000 miles of service. Steel tire wheels ought to run 40,000 miles before the first turning; ought to be good enough to be turned four or five times, and finally accomplish 200,000 miles. Considering that a chilled cast iron passenger wheel is bought subject to a guarantee of 60,000 miles, the guarantee is to the effect that if the wheel fails to accomplish that distance a new wheel is to be delivered by the contractor without cost to replace the defective one. A wheel mileage record is therefore kept for all passenger car and engine wheels. No mileage record is kept for freight car wheels. They are bought on a time limit guarantee, say about two years for ordinary chilled cast iron wheels. The wheel mileage account is made up from the car and locomotive mileage record kept by the car accountant from the daily reports made by conductors, as previously mentioned. The locomotive mileage account is also kept in the office of the general master mechanic from daily reports made by locomotive engineers. It is of interest to consider the oil contracts and the method adopted to maintain the quality of oil at a high standard. Contracts for lubricating and cylinder oils are made on a basis of yearly settlements, with the guarantee that total yearly cost shall not exceed an agreed and fixed sum per 1000 miles of car or locomotive mileage as the record is kept by the car accountant.

Information of interest and value may be gathered from a study of the following table, which is a monthly showing of performance of locomotives, and comparison with the same month in the preceding year:

| | Total 1901. | Total 1900. |
|---|---|---|
| Passenger locomotive mileage | 1,235,912 | 1,259,514 |
| Freight locomotive mileage | 609,797 | 634,481 |
| Mixed train locomotive mileage | 24,110 | 12,518 |
| Helping locomotive mileage | 22,512 | ........ |
| Light locomotive mileage | 78,062 | ........ |
| Switching locomotive mileage | 539,374 | 442,846 |
| Work locomotive mileage | 66,725 | 57,688 |
| Pay locomotive mileage | 912 | 895 |
| Total miles run | 2,577,404 | 2,407,942 |
| CAR MILEAGE. | | |
| Mileage passenger cars | 5,256,199 | 5,180,691 |
| Mileage freight cars, loaded | 13,408,915 | 12,390,820 |

| | | |
|---|---|---|
| Mileage freight cars, empty | 4,822,641 | 4,051,669 |
| Average cars per train—Passenger cars | 4.30 | 4.10 |
| Average cars per train—Freight cars, loaded basis | 25.40 | 22.50 |
| Average cars per train—Actual number of freight cars in train | 29.30 | 25.70 |
| **OIL AND WASTE.** | | |
| Pints of kerosene oil | 66,464 | 61,302 |
| Pints of signal oil | 9,924 | 8,859 |
| Pints of engine oil | 102,961 | 95,566 |
| Pints of valve oil | 30,334 | 26,177 |
| Pounds of string and cop waste | 37,633 | 35,750 |
| Pounds of wool waste | 751 | 875 |
| **COAL AND WOOD.** | | |
| Tons of anthracite coal | 2,755 | 2,883 |
| Tons of bituminous coal | 108,914 | 98,444 |
| Cords of wood | ........ | 919 |
| **COST.** | | |
| Repairs | $118,091.27 | $141,263.08 |
| Fuel | 297,980.24 | 250,914.33 |
| Lubricating oil and waste | 7,587.57 | 6,709.62 |
| Wages engineers and firemen | 178,514.23 | 172,082.91 |
| Wipers | 14,393.59 | 15,036.45 |
| Total | $616,566.90 | $586,006.39 |
| **COST PER MILE IN CENTS.** | | |
| Repairs | 4.58 | 5.87 |
| Fuel | 11.56 | 10.42 |
| Lubricating oil and waste | .29 | .28 |
| Wages engineers and firemen | 6.93 | 7.15 |
| Wipers | .56 | .62 |
| Total cost per mile | 23.92 | 24.34 |
| **FUEL PER CAR PER MILE.** | | |
| Passenger, pounds | 17.60 | 16.80 |
| Freight, pounds | 5.70 | 5.40 |
| **AVERAGES.** | | |
| Miles run to one ton of anthracite coal | 38.23 | 30.62 |
| Miles run to one ton of bituminous coal | 22.61 | 24.46 |
| Miles run to one pint of engine oil | 25.03 | 25.20 |
| Miles run to one pint of valve oil | 84.97 | 91.99 |
| Miles run to one pint of all lubricating oil, | 19.34 | 19.78 |

While on the subject of the machinery department, it may be of interest to consider some of the dimensions, etc., of a fast passenger locomotive of modern type of the year 1900. It is an eight-wheel engine, with cylinder 20″ diameter x 26-inch stroke; drivers, 78 inches diameter; boiler, 62 inches diameter; 312 flues, 12 feet

long each, with 88,000 pounds on drivers, 133,000 pounds total engine and 232,000 pounds engine and tender. A driving-wheel base of 8 feet 6 inches; total engine, 23 feet 9 inches, and engine and tender, 51 feet 8 inches. The tank capacity of the tender is 4500 gallons.

Another pattern. A heavy Mogul freight locomotive, with cylinders 20″ diameter x 28-inch stroke; drivers, 62 inches diameter; boiler, 62 inches diameter; 312 flues, 12 feet long each, with 125,000 pounds on the drivers, 145,000 pounds total engine and 243,000 pounds engine and tender. A driving-wheel base of 15 feet 6 inches; total engine, 23 feet 4 inches, and engine and tender, 51 feet 10 inches. The tank capacity of tender is 4500 gallons.

The purchasing department is in charge of a purchasing agent, assisted by a stationer and storekeeper. As far as it is possible it is the aim of the management to have all material for the company's use bought by one officer or department; and he, as the purchasing agent, with the natural genius of a merchant and trader, is expected to know just what sort of an article is needed in all departments, just where to go to procure it and just how to buy it at the best advantage. I may say that it is only in the case of placing heavy contracts, such as for rolling stock, rails, fuel, etc., and for heavy construction work which may require material in its prosecution, that other officers attend to such matters, except perhaps that at certain times, when there is urgent need for prompt delivery, certain heads of departments may secure material in anticipation with the knowledge and approval of the purchasing department.

The routine work of the department is as follows: Heads of departments having a clerical force sufficient to keep a proper record of requisitions and bills prepare requisitions or schedules of materials needed for the prosecution of their work at regular monthly intervals as far as possible. Such requisitions, forwarded through their next superior officers, in all departments, after being approved, reach the purchasing agent. The purchasing agent sends invitations to different dealers, if the quantities and cost of articles are of sufficient importance, inviting proposals. When an award is made, the purchasing agent, numbering his order so as to identify it with its proper requisition, sends it to the dealer selected with an original, duplicate and triplicate copy of a bill in blank form, which is to be filled out and forwarded by the dealer when goods are shipped. The order issued gives shipping directions, states details of price, whether freight is to be prepaid or otherwise. The dealer sends the triplicate copy of the bill with the goods to

the person or officer marked in the shipping directions on the order, and sends the original and duplicate copies to the purchasing agent at the same time. The purchasing agent sends these bills through the head of the department to the office where the original requisition was written. On the delivery of goods, the person or officer receiving the triplicate bill checks the quantity and quality, approves the bill if found correct and so notifies his superior, who then approves all three of the bills, making notes on same to inform the accounting department how to distribute the expense; files the triplicate bill for his own department records, and returns the original and duplicate through his immediate superior, each in turn approving same, and these latter are then returned to the purchasing agent.

The purchasing agent, retaining the duplicate for his files, approves the original and forwards it to the accounting department to be audited, entered on the books and finally paid by the treasurer. In the accounting department the bills of one dealer, who may have a running account and furnish material for more than one department, are assembled, a voucher written for the total of all and payment made of the combined amount or balance of account at stated intervals.

In the foregoing pages I have already taken up more than enough of your time, and taxed your patience up to the limit in listening to dry details, without having as yet made more than a passing mention of the accounting department, the pay department and the treasury department. On these departments alone a lengthy paper of interest might be written. Other departments and subjects of interest have been passed by for want of time rather than from lack of inclination, the main purpose having been to present for your consideration a description of those departments which are directly associated with the movement of trains, the handling of traffic and collection of earnings, the purchase of materials and the construction, maintenance and care of roadbed and of rolling stock.

## DISCUSSION.

President L. B. Bidwell.—We have with us this evening Mr. James H. French, whom I have long known as an excellent railroad superintendent, and have asked him to hear Mr. Sampson's paper, and, if so disposed, to give us his idea of the best railroad organization.

Mr. James H. French.—I appreciate the kindness of your President in extending an invitation to attend the meeting of this evening and listen to the very interesting paper by Mr. Sampson,

but I can hardly look with equal favor upon the annexed suggestion that I add some supplemental remarks. In fact Mr. Sampson has entered into his subject with a minuteness that has practically covered that which I was prepared to say, and there seems but little left for me to do but to take my hat and depart. But having promised to say something, I must do it, especially as I lay claim to being a descendant of a civil engineer.

My Grandfather French was a Revolutionary soldier, and at the close of the war found himself quartermaster in Castle William, Boston Harbor, the site of which fortification is now covered by Fort Independence.

He was a native and resident of the then little village of Randolph, about fifteen miles south of Boston, where the year's schooling was comprised within a month or two of the winter. The amount of education obtained was correspondingly small, and the quality necessarily inferior.

Among the hangers-on at the Castle was an old Scotchman, college bred, formerly wealthy, but broken down by reverses and dissipation and dependent upon the charities of the troops for whatever he had in the way of clothing, food and drink. For drink every soldier had his ration of grog, and that was what the old man most coveted; and it occurred to my grandfather, who cared little or nothing for the liquor, that here was an opportunity of extending his learning and bettering his circumstances upon his home return by exchanging drink for tuition. Such an exchange was arranged, and he began studying surveying, aided by some old books upon the subject that were picked up about the fort.

The old man was able to bring his shattered faculties into the sphere of teaching only after repeated trials and many tears, but succeeded so well in the end that my ancestor was enabled, after his discharge from the service, to do the town surveying for many a year.

In speaking of railroad organization I would say that I am now out of railroad service, after a period of employment that upon a street railway would have placed nearly nine stripes upon my sleeve, and that during my brief period of rest I have been divesting my mind of all thoughts of the cares and responsibilities attached to such service.

So I have not been troubling myself as to railroad organization and operation except so far as to expect such results therefrom as will transport me speedily, comfortably and safely when I have occasion to travel upon the rails. And the great public also expects the accomplishment of speed, comfort and safety by means of the

best appliances and methods, and the matter of comfort includes that of their pocketbooks, so that while the best of everything is expected,—roadbed, bridges, track, signals, cars, locomotives, stations, etc., to say nothing of men,—the company has to contend with a constant demand for minimum rates, and the candle is burning at both ends.

As all these items of renewals and maintenance represent heavy and constant outlay, and as there must be afforded some comfort to the poor stockholders in the shape of dividends, it becomes a matter of good and shrewd management to accomplish the desired results, and economy becomes a factor of larger proportions year by year.

Economy does not necessarily mean cutting things down to the lowest notch, working with scant force or inordinate hours, nor the use of inferior materials or too cheap labor. But there is an economy which discerns the happy medium; that obtains a good thing at bottom price, and the best endeavors of its employes at all times.

And here is where organization and efficiency show forth. It is not practicable to lay down one hard-and-fast rule for defining the minutiæ of organization. The size of a road, the nature and volume of its business, its location,—a thousand things enter the problem. A road may be so small as to permit its president (and every corporation must have that head) to act as general manager, general superintendent or to directly manage its traffic departments; while another road may be of such larger dimensions that there must be a chairman of board of directors, a president and assistant, vice-presidents in charge of finance, law and real estate, engineering and construction, traffic, etc., with general manager, superintendent of transportation, traffic managers, general passenger, ticket, baggage and freight agents, chief engineer, treasury and accounting departments, rolling stock department, and so down to the operating department, with its superintendents and its road, bridge, carpenter, station and train forces.

When a road is small, there is not much trouble in defining the scope of the several departments and the authority of their chiefs. But when the road becomes large and unwieldy there must be a refinement of organization, that scope and authority may be so clearly indicated as to insure harmonious and economical working; for a lack of such adjustment produces misunderstanding, misinterpretation and friction, and consequently undesirable results. The simpler the organization that meets the requirements the better, and, of course, the less expensive.

The fewer hands that matters have to pass through the more desirable, for it seems sometimes as if measures would die of circumlocution en route. Whatever organization is effected, it must be such as to work cordially within itself, and toward that end regular and stated meetings of co-ordinate departments, wherein may be free interchange of ideas and experiences, have a healthful tendency.

And when you have your road and your organization established, start in with a system of growing your own men so far as is possible; bringing them up on your own road, so that they may know its ins and outs, and that they may feel a personal interest in it beyond the simple matter of the weekly payroll, and that they may be in training for higher positions which time will surely produce. Establish a care for and interest in their welfare. Do something in the way of a pension system, that they may have an increased incentive to remain with you and do their level best, always having in mind that there is provision for the day when debarred from further labor by reason of sickness, accident or age.

When necessary to discipline your employes, do so by modern methods, rather than by the old and harsh system of suspensions. Above all, when you have put a man in authority, let him have that authority and sustain him in it.

There is one matter of organization that I wish to speak of, a matter that is of importance and which differs in practice upon different roads. I refer to the relations between the operating department (represented by the division superintendent) and the engineering department. Upon the Pennsylvania road, I believe it is the practice to make the division superintendent *the head* of all that is included within the limits of his division, which also places him in charge of the engineers, firemen, car cleaners and inspectors, locomotives and the engineering corps, which practice is different from hereabouts. Whatever the system, the superintendent should have full knowledge of all work upon his division, and should be brought in consultation relative to intended changes and improvements. His experience and his acquaintance with the doings and needs of his portion of road, and the fact that he has got to operate the same, ought to make his judgment of value in the location and planning of stations and the laying out of his passenger and freight yards; but I have known cases where work was found in progress of which he was uninformed, or merely had heard rumored. On the other hand, there have been cases of new track work of which the engineering department was not cognizant.

I once received instructions to build a piece of second track and to call upon the engineering department for any lines I might want. It was a short piece, between two and three miles only, and almost straight and level at that, and I only had to ask the assistance of the engineers as to an overhead bridge and the junction track arrangement at one end; but though the engineers considered it as rather an irregular matter, I think Mr. Bidwell will agree that it was accomplished without friction.

There are many and frequent jobs in maintenance and repairs calling for skillful engineering, and it has often seemed to me that there would be some advantages in having the track and bridge work under the engineering department. On the other hand, there are countless jobs that must come upon the track force that are entirely separate and distinct from the engineering department, where the superintendent would of necessity be a constant borrower were not the men on his rolls.

It is a subject that has received much consideration in the past, and will undoubtedly have to receive much more before there arrives such consensus of opinion as will warrant one general method.

Prof. C. Frank Allen.—In relation to the question of the advisability of the division superintendent having complete authority over his division, including control of the division engineer and division master mechanic, rather than having these officers report to the chief engineer and superintendent of motive power, it appears to be the case that the tendency at present among railroads is in the direction of giving the division superintendent complete authority over his division. Such is the Pennsylvania Railroad practice, as well as that of many other railroads. It is possible that one explanation of this tendency may be found in the fact that engineers to-day, and for some time past, have been far better educated than was previously the case, inasmuch as they have been technically educated, and on fairly broad lines. It is true, further, that the technically educated engineers are to-day better educated for such duties than was the case thirty years ago. It would certainly be unfortunate if this were not the case. Men are broadly educated now and have a suitable appreciation of the properties and behavior of materials and of the properties and use of steam. There is some propriety in placing the control of all the work of a division in the hands of a man capable of intelligently handling questions for which such an education suitably prepares him. It would be improper to dwell upon this view of the case without saying something in a different direction, and paying a tribute to the

splendid results that have been reached by the railroads of this country with men who were not technically educated, because the conditions would not allow them to secure this advantage. It is nevertheless true, or at least extremely probable, that these men who have made so successful a record would have been even more effective in their work if it had been possible for them to secure in their youth the advantages of a complete engineering training.

In relation to another point, where the paper has stated in effect that the American railroads have the most perfect railroad organization in the world, it would be proper, in the speaker's judgment, to go somewhat further and say that the American railroad presents the most perfect business organization of any kind that exists on a large scale anywhere in the world. And one feature which has made this organization so successful has been that of late years it has been necessary, in order to secure the best results, to first select employes by proper tests of fitness, and then hold them to good work by what may be called a sort of civil service system of promotion in due line and with regularity, which makes advancement in due time practically certain. The time has gone by when a large railroad system can be successfully handled on the basis of favoritism or the caprice of those in control. While it is reasonable and proper that under a change of management certain prominent officials should be changed, it is necessary that the rank and file should be reasonably assured of the certainty of promotion as the result of faithful work.

The railroad system has a distinct advantage over the public service system, or what we know as the civil service system, because the latter does not really present the ideal means for securing the best men. No system of examinations is so effective in securing good men as a system which gives to a man who desires only what is right the opportunity to secure, by recommendation and inquiry, those men who seem best fitted for the work to be done. On a railroad, there is opportunity for selection upon this basis; in government service the opportunity for abuse renders the civil service system that we know about more effective than the system of selection that would naturally prevail, and which has prevailed, when offices are given out as the reward of partisan service. The civil service system is therefore not ideal, but is simply the best available under the conditions of government service, and in this view it deserves our unflinching support. The opportunity for the railroad to secure and to hold good men is, however, exceptionally good, and not a little of the effectiveness of our railroads is due to that fact.

## THE LAWS OF RIVER FLOW.

By C. H. Tutton, Member, Engineers' Society of Western New York.

[Read before the Society, January 7, 1902.*]

The writer lately presented to the American Society of Civil Engineers a paper treating generally of the subject above named, based on the laminar theory of flow. This brought forth a private correspondence with D. T. Smith, M.D., of the Louisville (Ky.) University, who completely upsets, or, at least, tilts very much, the laminar theory by the remark, "If, as generally held, water moves along in streams by strata or layers, one gliding over another, the result of such action could not be the formation of channels." Dr. Smith has placed in the writer's hands a little book, being a collection of essays by himself, entitled "The Philosophy of Memory," of one of which, bearing the title of the present paper, it is proposed to give a short abstract. Although the theory contained therein was first enunciated in the early eighties, it seems not to have been sufficiently placed before engineers to meet the reception which it is believed should have been accorded to it. It is certainly worth examination. Further than this, the writer expresses no views of his own.

Prof. James Thomson (Trans. Brit. Assn. for the Adv. of Science, held at Glasgow, 1876, p. 31) says, in speaking of the motion of water in bends, "The bottom layer flows inward obliquely across the channel toward the inner bank, and rises up in a retarded condition between the inner bank and the rapidly flowing water and protects the inner bank from the scour, and brings with it sand and other detritus from the bottom, which it deposits along the river bank." Again, Maj. Allen Cunningham (Roorkee Hyd. Expts., Vol. I, p. 269), as a result of his experiments on the Ganges Canal, says: "Near the edge there is a persistent flow (of the water at and near the surface) from the edge toward the center, and this action is most intense nearest to the edge, and decreases rapidly with the distance from the edge." Dr. Smith had previously arrived at substantially the same conclusions from observation only, but in a greater degree of perfection, and promulgated his "Law of the Double Spiral," which the above observations only confirm, since if the outward bottom motion exists in bends, according to Thomson, it must also exist in a lesser degree in a straight line, else Cunningham's results could not obtain.

*Manuscript received January 10, 1902.—Secretary, Ass'n of Eng. Socs.

The premises upon which Dr. Smith bases his theory differ radically from those of any proposed thus far. He supposes that the water flowing in a stream may be conceived of as a succession of thin sheets formed of vertical columns of molecules, similar, for instance, to a lot of thin rods, and that the resistance to their motion is concentrated at their feet, or at the bed of the stream. Then, since their lower ends would be retarded, it would follow that, when motion began, they would all tip over and lie down flat, and the stream would disappear. In other words, unless by some mechanism as yet unsuggested, the columns can receive additions to their lengths, enabling them to reach the surface at its required level, the stream must eventually fail and disappear from its very flatness. The same effect would be felt from the banks if such existed.

In order, then, to avoid this result, he proposes the following theory of the

FORMATION OF STREAMS.

Suppose a quantity of water be found upon a smooth surface of erosible material, having sufficient incline to determine motion of the liquid. Now conceive such a stream to consist of columns of molecules as above described; then, first, the water will run down such incline in a thin stratum, whose outer walls will be held together by that form of adhesion known as surface tension. In the stream thus supposed to be formed, the column of particles at the outer edge, on each side and next within these walls, will be retarded more than any of the columns within, and, on account of friction, the particle at the lower end of each external column will be the most retarded of all, so that, if new force is not imparted to it, it must in time come to a standstill.

However, the lines of particles following each other in this order, that is, nearest the bottom and nearest the edge, will not be uniformly retarded even in the smoothest channel, for the lines will be pulled apart times innumerable. And since the width of the stream must be maintained and its area conserved in order that a constant quantity of water may pass any given point, whenever such a break begins to occur, that is, whenever a gap in the line is forming, it must be filled from the column of molecules next within, for the reason that there is none on the outside from which it can be filled.

Now, the column of particles next on the inside has a greater speed than the outer one, and from whatever part of such column the particle may be supplied, it will be moving faster than the one it may have supplanted.

If a rod were thrust to the bottom of a mass of water, however deep, and then drawn out instantaneously, the hole thus made would fill first at the bottom from the contiguous particles surrounding it. Likewise where there is a tendency to form a vacuum, and a suction is produced thereby, this forming vacuum will be supplied or filled by a molecule from the bottom of the next column within. Thus the molecules will constantly change places, causing outward motion along the bed, and this process will continue until the middle of the stream is reached.

When the stream has been equally divided on the basis of retarding forces, the molecules displaced by this outward motion must be replaced from above, causing a constant downward motion at the middle of the stream or in the line of the current.

The outward movement of the particles at the bottom of the stream will be attended by a momentum proportionate to its extent, and the result will be that, as these outward moving particles strike against the bank, and can go no farther, the water there will be lifted up and an elevation or ridge will be formed along each edge of the stream, so that its surface will take the form of a trough, and the water will, of course, return to the center in lines sloping in two directions.

In obedience to these laws, then, every stream moving in a channel of resisting material resolves itself into two cylinders, revolving spirally on parallel axes in opposite directions; that is, outward at the bottom, upward at the margins, inward at the top and downward through the middle. This is the "Law of the Double Spiral."

## SHAPE OF CHANNELS.

It is obvious that when the water of the upper part of a stream leaves the banks to begin its flow to the middle, it continues to increase its speed, not only until it reaches the point where in turn it must change its course obliquely downward, but also for some distance beneath the surface.

The water of the most rapid part of the stream, therefore, has also the most direct course downward; consequently, the greatest scour or erosion will occur at this section, accounting for the fact that every stream is the deepest in the line of its current. But this water, in passing downward, begins to suffer retardation before reaching the bottom, where its speed is usually less than at the surface, continues to decrease in speed and erosive power as it passes outward toward the banks until this erosive power is lost, when, rising toward the top, it again begins its movement toward the center. This motion, therefore, also

determines the width of the channel, and in homogeneous material should result in one of trough shape. (Experiments have shown that this is usually of elliptical form.)

Dr. Smith then goes on to explain why it is that the beds of shallows or ripples are found covered with boulders and large stones, notwithstanding the fact that the velocity in these places is increased; also why it is that pools generally have bottoms of the finer material. This is based on an assumed relation between depth and speed of current, assumed, however, only for the purpose of the illustration in hand. He finds that "the erosive power of a stream must have a relation to depth as well as to speed," and that during floods the same additional height is added to the deep and shallow parts of the stream. This adds more to the speed of the deep water than it does depth to the shallow water, and so sends the normal speed point downward faster in the deep water than in the shallow, when the product of the depth by the speed becomes greater in the deep water than in the shallow. This causes the coarser material to be raised from the deeper and deposited in the shallower portions of the channel.

### MOTION OF DRIFT TOWARD THE CENTER.

This theory explains why drift goes to the center of a channel, and holds that the water carrying such drift goes with it. Objections made to this by river men, who state that in floods the drift tends to move from the center toward the banks, are met by the reply that a river must rise before it can fall, and drift must be carried to the center before it can move away from it. In bends, where the current tends toward one of the banks, and consequently one spiral is more or less crowded out, overlapped, or even buried by the other, drift would certainly go with the current to the bank, and the water might sink at the bank instead of in the middle; but the motion will still be found to be outward at the bottom, as may be proven by examining the bed of a stream after a flood, when the coarser material will be found at the center and progressively diminish in size going outward. Evidently the coarsest material could only be dropped by the swiftest current.

### WHY MAXIMUM VELOCITY IS BELOW SURFACE.

After speaking of Boileau's experiments, and those of Humphreys and Abbot, and giving Prof. James Thomson's theory of the cause of maximum velocity being below the surface, the latter is modified to give a more rational explanation.

Prof. Thomson suggests "that portions of water, with their velocity diminished from retardation by the sides and bottom, are thrown off in eddying masses and mingle with the rest of the stream. These eddying masses modify the velocity in all parts of the stream, but have their greatest influence at the surface. Reaching the free surface, they spread out and remain there, mingling with the water at that level and diminishing the velocity which would otherwise be found there."

To this Dr. Smith replies that, in the first place, neither pressure in the water constituting the lower layers of the stream nor its retardation would operate to carry it to the surface, either in eddying masses or otherwise.

In the second place, if masses of water should begin to rise to the surface after or because their motion had been retarded, it would be necessary for them to make their way through the more rapidly moving central portions, and they would necessarily acquire thereby a similar motion.

But in the principle of the double spiral, the waters in contact with the channel walls are retarded by friction as they make their way along the bottom toward the edges of the stream, this retardation diminishing from below upward. It reaches its greatest extent at the margins, where the water, rising, spreads over the surface, or rather rolls over toward the middle as the upper half of the stream. This spiral must not be supposed to revolve as if made of sheets of paper that retain their places. All along the edges of the stream and over the bottom there will be irregular breaks. The water will fly off in diminutive masses here and there, and near the edges of the stream these will be seen boiling up through the free surface. A beautiful illustration of this may be observed at any time by looking down from a bridge onto the surface of a swollen stream.

Probably one-fourth of the stream on either side will be seen boiling up irregularly throughout its whole extent; within this will be seen a smooth belt, while at the middle there appears a narrow band, rough with waves or ripples.

This rough surface is probably due to slack, as well as to greater speed, the water moving in from the sides faster than it can sink down in the middle. The roughness of the small band in the middle of streams, known as the current, cannot result from mere speed alone, because the smooth band on each side of the current may at the same time be moving very much faster than the rough-surfaced current of the smaller streams.

The controlling condition of the depth of this maximum velocity is that the same quantity of water must move out below the maximum line that moves in above it.

Dr. Smith then proceeds to show why streams are higher at the middle than at the margins, although theoretically they should be lower; also why delta streams throw up natural levees, and why deltas have many mouths.

The only other point that will be here mentioned is his explanation of why water flowing in steep channels does not increase in speed as do solid bodies descending the same incline.

This explanation is that, since the transverse current in a stream depends altogether upon the friction against its channel wall, it will increase its angle to the stream axis in proportion to the shallowness of the water and the rapidity of the flow; that is, the pitch of the helix rises as the speed increases. Thus, in a deep, slow-moving stream, the spiral flow, or helix, will be very oblique; but in a swift stream it will have a greater angle with the stream axis, consequently each particle of water in a mountain torrent flows a much greater distance in accomplishing a mile of progress in its channel than a like particle in a deep, slow-moving stream. This also gives the reason why the speed of streams bears no constant relation to their inclination.

A further argument proving an outward current at the bed of a stream is given by the fact that bodies of drowned persons, no matter in what part of the river the drowning may have occurred, are found almost invariably at the banks, being carried there when they begin to decompose (and arrive at the same specific weight as the water) by the under and outward current.

There are a number of other interesting subjects, as motion of glaciers, etc., taken up by Dr. Smith (whose essay is some seventy pages long), but the preceding gives a general view of his theory.

## CONCRETE CONSTRUCTION.

FURTHER discussion, May 7, 1901,* of paper by L. R. Neher, read before the Engineers' Society of Western New York, March 5, 1901, and published in the JOURNAL of April, 1901, Vol. XXVI, No. 4.

MR. NEHER.—In *Engineering News* of March 28th is an interesting article on experiments with wet and dry concrete, by Mr. Irving Hitz. Two cubes of concrete a yard each were made, one cube being wet and the other ordinarily dry. There was a marked difference in the time it took to fill the boxes with the mixture—thirty-five minutes for the dry and twenty minutes for the wet, the difference in time being due to the tamping required to properly compact the dry mixture. The wet mixture was denser than the dry, weighing 340 pounds more than the dry mixture, and it had a finished surface, while the dry did not. In breaking up the concrete, the wet mixture was much harder to break than the dry. The cube of dry cement broke vertically down to the center of the cube, and then followed the horizontal layer which marked the top of the first batch, and in the dry mixture it was noticed that the second batch did not make a perfect union with the first batch. The interior of the wet cube was a solid compact mass, with most of the pieces of the limestone and granite pebbles broken across the line of the fractured cube. This is the substance of the article, and it carries out my idea of the matter. I am a believer in the wet mixture, and it takes very much less time to tamp the wet than the dry mixture, but I had no idea the difference was so great.

MR. FRUAUFF.—Were the cubes both the same size?

MR. NEHER.—Yes, sir.

MR. FRUAUFF.—Do you know what caused this great difference in time in tamping the layers?

MR. NEHER.—In the wet mixture you have just to dump in a batch and tamp it. In the dry the layers had to be tamped separately, and it took more time to thoroughly compact them.

MR. NORTON.—Do not most engineers advocate a dry mixture?

MR. NEHER.—They advocate the dry mixture, but I think you get better work in every way with the wet mixture.

MR. FRUAUFF.—By wet mixture you do not mean extremely wet, do you?

MR. NEHER.—Yes, sir; extremely wet.

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*Manuscript received December 22, 1901.—Secretary, Ass'n of Eng. Socs.

Mr. Norton.—I saw a concrete block being made for the Breakwater, and there was one inch or more water on top.

Mr. Neher.—The men have to wade in up to their ankles.

Mr. Fruauff.—In the wet mixture, is not the cement washed off the stone and held in suspension during the two or three minutes you are waiting for the second layer?

Mr. Neher.—We do not find it so, because the mixture is so dense that each layer works into the other. You could not call each batch a layer. There is no way of telling where one batch leaves off. They are all merged into one another. This is done by tamping thoroughly. The tampers which I have used are made of $\frac{5}{8}$-inch iron, a small piece being cut off and welded at right angles. We have also used the ordinary tampers. When the mass is properly tamped, it is one compact mass, and there are no layers in the wet mixture. There is a great saving in time in making the batches, the mass is very much harder than any dry cement concrete that I have ever seen, and it is very much harder to take down than the dry mixture. For instance, at the Dakota elevator it was necessary to cut down one of the piers 4 feet and build it up again, and it was wonderfully hard. The American Bridge Company were to put bolts in the piers. They failed to furnish me with plans showing where the holes were to be, and I went ahead and built the piers. They had to drill 120 holes for the bolts, and they found it pretty hard work.

Mr. Fruauff.—Have you had any experience with natural cement?

Mr. Neher.—No, sir. I am not an advocate of natural cement at the present price of Portland. In using Portland cement you know what to expect, but you don't know how the natural will act.

Mr. March.—Will not the wet mixture set more slowly than the dry?

Mr. Neher.—Not at this time of the year. In extreme cold weather, and if you have a tendency toward frost, it certainly retards it.

Mr. Fruauff.—An excess of water retards the setting, does it not?

Mr. Neher.—Yes; I think it would. I noticed to-day that, even as wet as we mixed it, we had a little delay in getting it put on; there was quite a decided set before it was covered. As soon as the water disappears from the surface, it begins to set. We got an average of 140 tons compressive strength inside of seven days right along. Our testing machine is only good for

120 tons. Some of the briquettes broke as low as 132 tons. Just what the exact average was I do not know, but I think it safe to call it 140 tons, and we know that we are getting the same thing every day. We sent a boy to the mixer to take out of any batch he might find, so as to eliminate the personal equation which might have affected the selection if we had made it ourselves.

Mr. March.—Did you make any tests of the dry mixture?

Mr. Neher.—No, sir; but I do not think you could get anything like 140 tons in seven days.

Mr. March.—Did you make any tensile tests?

Mr. Neher.—No, sir. In our work, we, of course, only use the work in compression, and that is the only value of it to us.

Mr. Norton.—Did not Mr. Rafter, in the State Engineer's report for 1897-8, lean toward the dry mixture?

Mr. Neher.—Very much so, and excessive tamping. I would like to see how he can economize on cement by using it dry and then tamping. The theory may be all right, but it won't do for the foreman on the work. It may be the thing in the laboratory, but I find that, with the ordinary laborer, and the care given to the concrete, we get better and more uniform results from a wet mixture.

The President.—Dr. Goodridge, in mixing his cement and sand, used to be very careful to get the exact amount of water required, even to half a pint.

Mr. Neher.—We could not be so exact on the work. This depends upon the season of the year and the aggregates used. We use lake gravel, not sand. Frequently we get wet and dry both on the same day from the boats, and often the broken stone contains more or less moisture. I do not think any man can tell more about it than the foreman; he can tell how it works under the tampers. Again, when there is frost in the stone, we get rid of the frost by the use of a little hot water, and sometimes even a little means enough to effect so exact an estimate. You cannot get the aggregates dry, and you cannot handle two lots of work alike. The weather itself has something to do with it.

The President.—I always thought Dr. Goodridge was rather precise in getting down to half a pint of water in a batch of a dozen or fifteen yards.

Mr. Neher.—The government calls for a dry mixture. This spring Major Symons has allowed us to use a wetter mixture, and we are trying to give him good work. The wet mixture sometimes receives less tamping than the dry. That is the one

disadvantage. The difficulty with the ordinary laborers is to get it tamped enough. This part of the work has to be watched carefully, on account of the larger amount of material used. By tamping we get the mixture uniform throughout. It is surprising how many now agree that the wet mixture is the best, who a year ago thought differently. The comparative cost between the dry and wet mixtures, so far as the labor is concerned, is between 10 and 15 per cent. in favor of the wet.

Mr. Whitford.—The Chilian engineers used the dry mixture.

The President.—How long were you in Chili, Mr. Whitford?

Mr. Whitford.—Three years.

Mr. Neher.—I think the saving in cost on the labor makes up for the extra materials used. That we get a denser mass, seems to me proof conclusive. What the results are, we know. We get more material in a given space than with the dry method.

Mr. Norton.—I would like to ask Mr. Neher if he has seen the work done by Mr. Roach in New York city?

Mr. Neher.—I saw the church at Brooklyn, and I saw the beginning of the work at the Mineola court house, but at that time they were at work on the foundation.

Mr. Norton.—Within a month I had occasion to go with Mr. Roach over the Mineola court house, and also visited the church in Brooklyn, and it is a very interesting piece of work. The concrete work of the court house in Brooklyn is practically finished. At the time I was there they were starting to bush-hammer. Mr. Roach did not say what it cost.

Mr. Neher.—I have bush-hammered for less than a cent and a half a foot, using the ordinary laborers at $1.50 per day. For abutments, I favor concrete as against masonry. For railroad construction, you can get the material quicker than you can get from the quarry the stone which would have to be used in such large construction. It means something to have to watch each course of stone laid. It is also easier to put the concrete under trains. For the rails I should lay it as for first-class masonry.

Mr. Norton.—In the Mineola court house there were a few fine cracks, which appeared in the floor. So far as I have been able to learn, they have done no damage, and only affect the appearance.

Mr. Neher.—At the cement works at Bayonne, a number of these fine cracks appeared. These were whitewashed over, and

they have caused no trouble. It would be natural, I think, to find these fine cracks in the basement of such a structure.

Mr. March.—Do you know whether they were caused by shrinkage or by expansion?

Mr. Neher.—I do not know exactly what is the cause.

Mr. March.—I do not think it is expansion, but that it must be caused by shrinkage. I do not think you can do anything more than wash them over, though they will show through.

Mr. Neher.—Mr. Norton, did Mr. Roach say he was making any money?

Mr. Norton.—I did not hear him say.

Mr. Neher.—I do not think myself that there is very much in it on ornamental work. On heavy foundation of floors there is a chance to get out a little better.

# ASSOCIATION OF ENGINEERING SOCIETIES.

## Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies and clubs hereunto subscribing have agreed to the following

## ARTICLES OF ASSOCIATION.

### ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "The Association of Engineering Societies." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

### ARTICLE II.

ORGANIZATION.

Section 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

Sec. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

### ARTICLE III.

DUTIES OF OFFICERS.

Section 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

Sec. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-

thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

## ARTICLE IV.

### PUBLICATIONS.

Section 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published, and shall forward the same to the Secretary.

Sec. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

Sec. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

Sec. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

## ARTICLE V.

### CONDITIONS OF PARTICIPATION.

Section 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

Sec. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

Sec. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

## ARTICLE VI.

### AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

## ARTICLE VII.

### TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.
Engineers' Club of Cincinnati, January, 1899.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

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## Annual Report of the Chairman of the Board of Managers.

DECEMBER 31, 1901.

*To the Members of the Board of Managers of the Association of Engineering Societies:*

GENTLEMEN:—I have the honor to present to the Association, through you, the annual report of the Chairman for the year 1901.

The principal business of the Board being the publication of the JOURNAL, and the entire work of the same being performed by the Secretary, I feel that the credit for the satisfactory appearance and continued popularity of the JOURNAL should be given to him. His work has been done with an attention to detail which has re-

sulted in a most satisfactory JOURNAL during the past year. The regularity of its appearance, quality of the papers presented and the execution of the work have maintained the JOURNAL fully up to the standard of former years.

As shown by the Secretary's report, the membership is now greater than at any time in the existence of the Association. Our financial condition is good; yet we are greatly lacking in the matter of the self-sustaining power of our JOURNAL. With the opportunities we have, there should not be the need of our paying for the JOURNAL, as it could easily be paid for by advertisements. Let each Society secure its share of advertising matter, and the expense of the JOURNAL would soon be reduced to a nominal amount.

Following the example of Chairman Shepardson, I have appointed an Auditing Committee to examine and report on the accounts of the Association for the past two years.

I take pleasure in transmitting herewith the annual report of the Secretary, which is in full detail and needs no comment other than what I have above mentioned.

In conclusion, I desire to express my appreciation of the honor conferred upon me, in selecting me a second time for Chairman of the Board, and I trust that I may satisfactorily perform the duties of the office.

Respectfully submitted,

JAMES RITCHIE, *Chairman.*

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## Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 31, 1901.

*Mr. James Ritchie, Chairman,*

413 Chamber of Commerce, Cleveland, Ohio.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1901, and of the condition of the Association at the present time.

These data are concisely stated in the following statistical appendixes:

A. Statement of receipts and expenditures during 1901.

B. Estimate of assets and liabilities at the close of 1901.

C. Detailed statement of cost of JOURNAL during 1901, by months.

D. Comparison of mailing lists of the JOURNAL at the close of 1900 and of 1901, respectively.

E. Statement of material in JOURNAL during 1901, by pages.

F. Comparison of conditions, 1894 to 1901, inclusive.

Appendixes C and F show a further increase in the cost of the JOURNAL. The three years 1899, 1900 and 1901 comparing as follows:

| December 31. | Members on Mail List. | Total Pages in JOURNAL. | Printers' Bills. | Illustrations. | Composition, Paper, Presswork and Binding. | TOTAL. | Cost of JOURNAL. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Per Page. | Per Member. | Per Member, per 1000 Pages. |
| 1899 | 1475 | 958 | $1858.00 | $561.24 | $2249.79 | $3233.44 | $3.38 | $2.19 | $2.29 |
| Incr. | 66 | 172 | 945.77 | 29.58 | 968.65 | 1118.09 | 0.47 | 0.63 | 0.21 |
| % | 4.5 | 18 | 51 | 5.3 | 43 | 35 | 14 | 29 | 9.2 |
| 1900 | 1541 | 1130 | $2803.77 | $590.82 | $3218.44 | $4351.53 | $3.85 | $2.82 | $2.50 |
| Incr. | 56. | . . . | . . . . | 570.08 | 380.57 | 505.11 | 0.67 | 0.22 | 0.33 |
| Decr. | . . . | 56 | 69.03 | . . . | . . . . | . . . . | . . . | . . . | . . . |
| % | 3.6 | 5.0 | 2.5 | 96 | 12 | 12 | 17 | 7.8 | 13 |
| 1901 | 1597 | 1074 | $2734.74 | $1160.90 | $3599.01 | $4856.64 | $4.52 | $3.04 | $2.83 |

As explained in my report for 1900, the increase of 35 per cent. in the total cost for that year, as compared with 1899, was due partly to a sharp advance in the printers' rates and partly to the increase of 18 per cent. in the amount of matter published.

During 1899, although the rates have remained unchanged, and the number of pages published has decreased 5 per cent., the total cost has increased by $505.11, or 12 per cent.; but it will be seen that this increase is more than covered by the increase of $570.08 (96 per cent.) in the cost of illustrations. In this respect, the year just past, with its total of $1160.90, has far exceeded any other year since 1893, and probably any other in the history of the JOURNAL. Among the papers involving large expense for illustrations during 1901, are those of Mr. Johnston, Cleveland, on "American Blast Furnace," in January; Mr. Fenkell, Detroit, "A Study in Hydraulics," in March; Mr. Cummings, Boston, on "Subaqueous Tunnels," in June; and Messrs. Ockerson, St. Louis, on "The Lower Mississippi," Tuttle, Boston, on "Grade Crossings," and Crotts, Louisiana, on "Sewerage of New Orleans," in November.

The close of 1901 shows a cash balance of $1368.48, decrease $79.76, and net assets (including cash) of $2062.72, decrease $99.95.

The net cost of the JOURNAL may be found as follows:

| | | | | |
|---|---|---|---|---|
| Gross cost | | | | $4,856.64 |
| Deduct receipts from | | | | |
| Subscriptions | | $694.51 | | |
| Less discounts | | 27.90 | | |
| | | | $666.61 | |
| Sales of JOURNALS | $222.37 | | | |
| " " Index | 175.25 | | | |
| | | $397.62 | | |
| Less discounts | | 10.95 | | |
| | | | 386.67 | |
| Sales of reprints | | $323.72 | | |
| Less cost | | 204.60 | | |
| | | | 119.12 | |
| Forward | | | $1,172.40 | $4,856.64 |

| | | | |
|---|---|---|---|
| Brought forward | | $1,172.40 | $4,856.64 |
| Sales of periodicals | | 61.05 | |
| " " electrotypes | | 26.45 | |
| " " postage stamps | | 2.00 | |
| Advertisements | $331.50 | | |
| Less discounts | 87.40 | | |
| | | 244.10 | |
| Extra copies of mail list | | 3.00 | |
| Interest on deposits | | 36.04 | |
| | | | 1,545.04 |
| | | | $3,311.60 |

This amounts to $2.07 per member, and the excess of 7 cents per member over the $2 assessment, on 1597 members, amounts to $111.79, which explains the slight falling off in net assets.

During the year no new societies have joined the Association, but the aggregate membership of our societies shows an increase of about 3.6 per cent. The present aggregate of 1597 members is greater than at any time during the history of the Association, exceeding, as it does, by about 8.1 per cent., the aggregate membership at the close of 1895, before the withdrawal of the Western Society of Engineers.

Appendix F shows a slight falling off (3 per cent.) in the volume of papers published, notwithstanding the increase of 3.6 per cent. in the number of names on the mailing lists of the Societies. The number (646) of pages published in 1901 is exactly equal to the average number for each year from 1894 to 1900 inclusive, as also to the average from 1894 to 1901 inclusive.

I have frequently called the attention of the Board and that of the Secretaries of our Societies to the arrangement by which the Association refunds, to any Society, 90 per cent. of the gross receipts from advertisements secured for the JOURNAL by such Society.

The Cleveland Club has taken notable advantage of this provision, its commissions on advertisements having at times covered the entire amount of its assessments due to the Association.

The St. Louis Club also has made a beginning in this direction, its rebate, on account of advertisements, in 1901 amounting to $36.*

As an instance of what may be done by a Society in this respect, I submit the experience of the Western Society of Engineers, as exhibited in the following comparison:

CONDITIONS AT THE CLOSE OF 1900.

| | Western Society. | Association. |
|---|---|---|
| No. of pages of advertisements† | 27 | 5 |
| Professional cards | 8‡ | 0 |
| Gross receipts from advertisements, 1900 | $2,157.50 | $370.83 |
| Membership | 503 | 1,541 |
| Circulation | 800§ | 1,943 |

In short, the Western Society carries about five times as much advertising space as does our Association, and enjoys a gross revenue nearly six times as great, more than covering the apparent cost of printing the JOURNAL, and yet our aggregate membership is three times that of the Western Society, and the circulation of our JOURNAL probably not less than two and a half

*As the report goes to press, February, 1902, the Secretary is in receipt of order for two advertisements from the Engineers' Society of Western New York.

†Only those pages are counted which are believed to yield revenue.

‡At close of 1901, 20.

§Estimated by assuming about 300 addresses for advertisers, exchanges and subscribers.

times that of the Journal of the Western Society, so that our JOURNAL is a vastly better advertising medium, even apart from the fact that our membership embraces that of eleven societies and is national in extent, reaching from the Atlantic to the Pacific, and from Montana and the Lakes to the Gulf of Mexico, whereas that of the Western Society is presumably located, for the most part, in the single city of Chicago.

In the light of the example of the Western Society, it ought to be an easy matter for our Societies to pay their assessments to the Society by means of the 90 per cent. commission allowed them on advertisements, and thus render the JOURNAL self-supporting.

Such a state of affairs would not only be most gratifying in itself, but would be of the greatest service as an inducement in securing the co-operation of Societies still outstanding.

The advertising pages of the Journal of the Western Society give every indication that the Society avails itself of the services of an advertising agent, and I submit that it would pay some, if not all, of our Societies to do likewise.

It is certainly remarkable that, with an aggregate membership of 1597 engineers in different branches, the advertising pages of our JOURNAL cannot show one professional card.

Arrangements have been made for the exchange of advertisements with a number of leading engineering publications, and under these arrangements notices are inserted in those journals announcing the papers published monthly in the JOURNAL. It is probably in great part owing to this practice that our sales of JOURNALS have increased, during the year, from $182 to $222, an increase of 22 per cent.

During the year *The Engineering Magazine* has brought out its Engineering Index for the five years, 1896-1900, inclusive, forming, in effect, the third volume of the Descriptive Index of Current Engineering Literature, the first volume of which, covering the eight years from 1884 to 1891, inclusive, was reprinted from our JOURNAL and published by our Board of Managers in 1892.

Volume II of this series, entitled "The Engineering Index," and covering the four years from 1892 to 1895, inclusive, was reprinted from our JOURNAL and published by *The Engineering Magazine*, with the consent of our Board of Managers, in 1896.

At the close of 1895 our Board directed the discontinuance of the publication of the Index in our monthly issues, and the preparation and publication of the third volume have therefore been solely the work of *The Engineering Magazine;* but in consideration of the Association's sponsorship of the original enterprise, and of its having contributed the material for the second volume of the series, the proprietor of the *Magazine* extended to the members of our Societies the privilege of subscribing, in advance, to Volume III, at $5 per copy, or one-third less than the regular price of $7.50.

While Volume II (covering four years) contains about 6000 entries taken from 62 journals, Volume III contains nearly 40,000 entries taken from nearly 200 sources, and more than four times as many entries per year as the earlier volumes.

Volumes I and II, covering eight years and four years, respectively, or twelve years in all, contained 475 and 474 pages respectively, or 949 pages (79 pages per year) in all, while Volume III (covering five years) contains 1030 much more closely printed pages, or 206 pages per year. Arrangements have been made by which the Secretary of the Association can supply copies of the third volume, as well as of the other two as heretofore.

Respectfully submitted,

JOHN C. TRAUTWINE, JR., *Secretary.*

## APPENDIX A.

### Statement of Receipts and Expenditures during 1901.

### CASH, 1901.

*Dr.*

| | | | |
|---|---|---|---|
| To Balance, January 1, 1901 | | $1,448.24 | |
| " Assessments, at $2.00 per member: | | | |
| Boston Society of Civil Engineers | $1003.00 | | |
| Civil Engineers' Club of Cleveland | 446.50 | | |
| Engineers' Club of St. Louis | 422.50 | | |
| Civil Engineers' Society of St. Paul | 55.50 | | |
| Engineers' Club of Minneapolis | 38.50 | | |
| Montana Society of Engineers | 279.00 | | |
| Detroit Engineering Society | 264.50 | | |
| Engineers' Society of Western New York | 69.00 | | |
| Louisiana Engineering Society | 141.50 | | |
| Engineers' Club of Cincinnati | 159.50 | | |
| Technical Society of the Pacific Coast | 283.00 | | |
| | | 3,162.50 | |
| To Subscriptions | | 694.51 | |
| " Sales of Journal | $225.27 | | |
| " Less refunded | 2.90 | | |
| | | 222.37 | |
| " Sales of Descriptive Index | $185.25 | | |
| " Less refunded | 10.00 | | |
| | | 175.25 | |
| " Sales of Reprints | | 323.72 | |
| " " " Periodicals | | 61.05 | |
| " " " Electros | | 26.45 | |
| " " " Stamps | | 2.00 | |
| " Advertisements | | 331.50 | |
| " Boston Society of Civil Engineers. Extra copies of mail list | | 3.00 | |
| " Interest on Deposits | | 36.04 | |
| | | | $6,486.63 |

*Cr.*

| | | |
|---|---|---|
| By Patterson & White Co. (Printers) | $3,131.16 | |
| " Illustrations | 1,064.47 | |
| " Secretary's salary | 600.00 | |
| " Car fares | .16 | |
| " Discounts on subscriptions | 27.90 | |
| " " " sales | 10.95 | |
| " " " advertisements | 1.00 | |
| " " " " (Civil Engineers' Club of Cleveland) | 86.40 | |
| " Messenger service | 4.09 | |
| " Envelopes | 7.25 | |
| " Stationery | 12.00 | |
| " Telegrams | 11.98 | |
| " Postage stamps | 63.79 | |
| Forward | $5,021.15 | $6,486.63 |

| | | |
|---|---|---|
| Brought forward | $5,021.15 | $6,486.63 |
| By Express charges | 1.40 | |
| " Freight | .25 | |
| " Binding copies of Vol. I of Descriptive Index | 11.93 | |
| " Binding Vols. XXIV, XXV and XXVI of JOURNAL, | 4.75 | |
| " Engineers' Club of Minneapolis. Binding reprints, | 2.00 | |
| " Mimeographing | 2.51 | |
| " Advertising. Two lots of circular letters announcing JOURNALS, including postage, etc | 58.12 | |
| " Telephone service | 11.04 | |
| " Proportion of Secretary's traveling expenses to Boston | 5.00 | |
| | | 5,118.15 |
| " Cash balance, December 31, 1901 | | $1,368.48 |

## APPENDIX B.

### ESTIMATE OF ASSETS AND LIABILITIES AT THE CLOSE OF 1901.

#### AVAILABLE ASSETS.

| | | | |
|---|---|---|---|
| Cash balance, December 31, 1901 | | $1,368.48 | |
| Less subscriptions for 1902, paid during 1901 | | 54.60 | |
| | | | $1,313.88 |
| Amounts receivable from Societies (for assessments, etc.): | | | |
| Boston Society of Civil Engineers | $7.75 | | |
| Engineers' Club of Minneapolis | 15.50 | | |
| Montana Society of Engineers | 50.25 | | |
| Engineers' Society of Western New York | 134.80 | | |
| | | $208.30 | |
| Subscriptions due: | | | |
| For 1901 | $66.00 | | |
| " 1900 | 51.00 | | |
| " 1899 and earlier | 276.00 | | |
| | | 393.00 | |
| For Reprints | | 109.35 | |
| " Advertisements | | 343.33 | |
| " Sales of JOURNAL | | 5.00 | |
| " " " Index | | 4.00 | |
| | | | 1,062.98 |
| | | | $2,376.86 |

#### LIABILITIES.

| | | | |
|---|---|---|---|
| Patterson & White Co. (Printers): | | | |
| For December JOURNAL | $184.96 | | |
| " Reprints | 20.55 | | |
| | | $205.51 | |
| Civil Engineers' Club of Cleveland, commissions on advertisements | | 61.20 | |
| Engineers' Club of St. Louis, commissions on advertisements | | 36.00 | |
| Illustrations | | 11.43 | |
| | | | 314.14 |
| Net Assets | | | $2,062.72 |

# APPENDIX C.

## Detailed Statement of Cost of Journal during 1901, by Months.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Composition. | Paper, Presswork, Binding. | Wrapping, etc. | Postage | Printer, Sum of 1, 2, 3 and 4. | Illustrations.* | Cost of Manufact'e Sum of 1, 2, 6. | Wrappers. | Sec'y Salary | Sundries.† | Total. Sum of 5, 6, 8, 9, 10 | No. of Pages.‡ | Cost per Page.‡ |
| January | $235 88 | $226 65 | $7 30 | $17 82 | $487 65 | $207 63 | $670 16 | $4 75 | $50 00 | $39 23 | $789 26 | 186 | $4 24 |
| February | 104 77 | 137 65 | 6 52 | 11 87 | 260 81 | 103 13 | 345 55 | 4 75 | 50 00 | 13 74 | 432 43 | 110 | 3 93 |
| March | 181 67 | 184 75 | 5 95 | 13 93 | 386 30 | 272 15 | 638 57 | 4 75 | 50 00 | 21 65 | 734 85 | 152 | 4 83 |
| April | 39 45 | 75 25 | 5 40 | 5 74 | 125 84 | 38 02 | 152 72 | 4 75 | 50 00 | 33 33 | 251 94 | 56 | 4 50 |
| May | 48 90 | 82 90 | .5 30 | 5 44 | 260 81 | ......... | 131 80 | 4 75 | 50 00 | 49 00 | 364 56 | 62 | 5 88 |
| June | 93 99 | 132 25 | 4 62 | 12 15 | 243 01 | 142 29 | 368 53 | 4 75 | 50 00 | 30 37 | 470 42 | 104 | 4 52 |
| July | 38 25 | 66 00 | 4 50 | 7 35 | 116 10 | 86 17 | 190 42 | 4 75 | 50 00 | 5 89 | 262 91 | 52 | 5 06 |
| August | 98 96 | 110 40 | 5 85 | 8 01 | 223 22 | 43 70 | 253 06 | 4 75 | 50 00 | 3 65 | 325 32 | 82 | 3 97 |
| September | 30 77 | 68 50 | 4 59 | 5 21 | 109 07 | 3 00 | 102 27 | 4 75 | 50 00 | 24 51 | 191 33 | 48 | 3 99 |
| October | 36 32 | 66 00 | 5 95 | 6 71 | 114 98 | 84 74 | 187 06 | 4 75 | 50 00 | 52 78 | 307 25 | 52 | 5 91 |
| November | 91 13 | 120 75 | 4 56 | 10 30 | 226 74 | 163 53 | 375 41 | 4 75 | 50 00 | 10 94 | 455 96 | 98 | 4 65 |
| December | 73 42 | 93 50 | 5 86 | 7 43 | 180 21 | 16 54 | 183 46 | 4 75 | 50 00 | 18 91 | 270 41 | 72 | 3 76 |
| Totals and averages | $1,073 51 | $1,364 60 | $66 40 | $111 96 | $2,734 74 | $1,160 90 | $3,599 01 | $57 00 | $600 00 | $304 00 | $4,856 64 | 1074 | $4 52 |

* The figures in column 6 (Illustrations) include preparation of cuts and lithographic stones, and paper and presswork on insets.

† The figures in column 10 (Sundries) include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡ The figures in columns 12 (No. of Pages) and 13 (Cost per Page) include 4 cover pages in each number, and 16 pages in indexes to Vols. XXVI and XXVII.

## APPENDIX D.

Comparison of the mailing lists of the Journal, at the close of 1900 and 1901, respectively:

| | 1900. | 1901. | Increase. | Decrease. |
|---|---|---|---|---|
| Boston Society of Civil Engineers....... | 501 | 505 | 4 | .. |
| Civil Engineers' Club of Cleveland....... | 208 | 231 | 23 | .. |
| Engineers' Club of St. Louis............ | 204 | 218 | 14 | .. |
| Civil Engineers' Society of St. Paul..... | 29 | 27 | .. | 2 |
| Engineers' Club of Minneapolis.......... | 13 | 29 | 16 | .. |
| Montana Society of Engineers.......... | 109 | 114 | 5 | .. |
| Technical Society of the Pacific Coast... | 136 | 141 | 5 | .. |
| Detroit Engineering Society............ | 105 | 118 | 13 | .. |
| Engineers' Society of Western New York.. | 72 | 78 | 6 | .. |
| Louisiana Engineering Society.......... | 74 | 58 | .. | 16 |
| Engineers' Club of Cincinnati........... | 90 | 78 | .. | 12 |
| In the societies composing the Association.. | 1541 | 1597 | 86 | 30 |
| **Net increase..................56** | | | | |
| Extra copies to Societies................ | 50 | 47 | .. | 3 |
| Advertisers .......................... | 14 | 14 | .. | .. |
| Exchanges ........................... | 116 | 120 | 4 | .. |
| Subscribers .......................... | 216 | 224 | 8 | .. |
| Complimentary copies ................. | 6 | 1 | .. | 5 |
| Totals ..................... | 1943 | 2003 | 98 | 38 |
| **Net increase..................60** | | | | |

Besides this, many copies have been sold and specimen pages sent out; and authors of papers have each received five copies of the Journals containing them. Two thousand two hundred and fifty copies of each number have been printed.

## APPENDIX E.

Statement of Material in Journal during 1901, by pages.

| | Papers. | Proceedings. | Chairman's Report. | Advertisements. | Indexes to Vols. | List of Members. | Totals. | Cuts. | Plates and Full-Page Cuts. |
|---|---|---|---|---|---|---|---|---|---|
| January.................. | 61 | 10 | 11 | 15 | | 85 | 182 | 25 | 8 |
| February..... ......... | 82 | 9 | | 15 | | | 106 | 37 | 8 |
| March.................... | 100 | 32 | | 16 | | | 148 | 33 | 10 |
| April......... ............ | 30 | 7 | | 15 | | | 52 | 14 | 1 |
| May....................... | 42 | 3 | | 13 | | | 58 | 2 | ... |
| June....................... | 77 | 2 | | 13 | 8 | | 100 | 3 | 8 |
| July....................... | 34 | 1 | | 13 | | | 48 | 11 | 4 |
| August ................... | 54 | 10 | | 14 | | | 78 | 26 | 1 |
| September............... | 26 | 4 | | 14 | | | 44 | 2 | ... |
| October.................. | 28 | 6 | | 14 | | | 48 | 12 | 5 |
| November............... | 76 | 4 | | 14 | | | 94 | 32 | 8 |
| December............... | 36 | 11 | | 13 | 8 | | 68 | 16 | 2 |
| Totals....... ...... | 646 | 99 | 11 | 169 | 16 | 85 | 1026 | 213 | 55 |
| Covers.......................................................... | | | | | | | 48 | | |
| Total........................................................... | | | | | | | 1074 | | |

# APPENDIX F.

## Comparison of Conditions, 1894 to 1901, Inclusive.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pages of Papers. | | Cost of Journal.* | | | | | Illustrations. | | | |
| Year. | Number of Societies in Association, Dec. 31. | Aggregate Membership of Societies, Dec. 31. | Subscribers, Dec. 31. | Exchanges, Dec. 31. | Net Receipts from Advertisements. | Total Number of Pages in Journal. | Total. | Per 1000 Members. | Total. | Per Page. | Per Member. | Per Member per 1000 Pages. | Annual Assessment per Member. | Small Cuts. | Plates and Full-Page Cuts. | Cost. | Net Assets, Dec. 31. |
| 1894 | 8 | 1174 | 176 | 110 | $671 00 | 1290 | 653 | 556 | $5774 59 | $4 48 | $4 92 | $3 81 | $3 00 | 86 | 54 | $651 60 | —$758 91‡ |
| 1895 | 11 | 1477 | 215 | 122 | 599 09 | 1482 | 792 | 536 | 5911 48 | 3 99 | 4 00 | 2 70 | 3 66 | 116 | 66 | 859 60 | 223 93 |
| 1896 | 9 | 1106 | 241 | 108 | 763 25 | 856 | 490 | 443 | 3928 42 | 4 59 | 3 55 | 4 15 | 3 00 | 62 | 56 | 771 39 | 1244 94 |
| 1897 | 10 | 1252 | 233 | 102 | 410 25 | 1016 | 638 | 510 | 3140 43 | 3 09 | 2 51 | 2 47 | 2 50 | 57 | 45 | 503 85 | 2562 04 |
| 1898 | 12 | 1370 | 246 | 114 | 465 58 | 1110 | 738 | 539 | 3462 08 | 3 12 | 2 53 | 2 28 | 2 00 | 166 | 42 | 729 38 | 2936 71 |
| 1899 | 11 | 1475 | 249 | 115 | 390 88 | 958 | 544 | 369 | 3233 44 | 3 38 | 2 19 | 2 29 | 2 00† | 124 | 30 | 561 24 | 2442 70† |
| 1900 | 11 | 1541 | 216 | 116 | 370 83 | 1130 | 666 | 432 | 4351 53 | 3 85 | 2 82 | 2 50 | 2 00 | 112 | 27 | 590 82 | 2162 67 |
| 1901 | 11 | 1597 | 224 | 115 | 331 50 | 1074 | 646 | 405 | 4856 64 | 4 52 | 3 04 | 2 83 | 2 00 | 213 | 55 | 1160 90 | 2062 72 |

* The publication of the Descriptive Index of Current Technical Literature was discontinued at the end of 1895.

† During 1899, with an assessment of $2.00 per member, the Association made a rebate of $1.00 per member for the purpose of reducing surplus, making the actual charge only $1.00 per member, and reducing the assessment by about $1400.

‡ Deficit at close of 1894. Since then, each year has shown a surplus.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

# ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXVIII. FEBRUARY, 1902. No. 2.





## TONNAGE RATING OF LOCOMOTIVES.

BY W. M. RAY, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club December 10, 1901.*]

THE practice of systematic tonnage rating of locomotive engines has been introduced extensively only since about 1895; but it is now prevalent on nearly all lines of railroad. The practice provides for the making up of trains by the actual weights of cars and lading to correspond with the maximum hauling capacity of each class of engines on the different divisions. It is a matter which concerns most directly the departments of motive power and transportation; but with the growing tendency to make the preliminary, if not the final, ratings by theoretical deductions from maps and profile, the department of engineering must be responsible for the data upon which the rating is based. Since about 90 per cent. of the railroad construction now under way in this country is on reduction of grade and curvature in existing lines, to meet the demand for increased tonnage on a basis of reduced train mileage, a practical knowledge of the conditions governing the performance of motive power of the line is a necessity. In 1898 it was the duty of the writer to assist in tabulating a motive power list for the Cleveland, Lorain and Wheeling Railway, and to make theoretical ratings for the purpose of comparison with the ratings made from actual trials on the road by our Superintendent. The first of these tests was made in June, 1896, and the ratings on our new class K engines were determined in June and December, 1900

*Manuscript received January 16, 1902.—Secretary, Ass'n of Eng. Socs.

While all the essentials underlying the theoretical rating of locomotives were developed by A. M. Wellington in his "Economic Theory of Railway Location," the practice seems to have been formulated first by Mr. G. R. Henderson, author of the report of the committee on tonnage rating for locomotives of the American Railway Master Mechanics Association in 1898. In this report the following result is given of a circular of inquiry sent out October 5, 1897: Forty-three roads in the United States, Canada and Mexico, operating 66,000 miles, reported that they were using the tonnage method; some had been so operated for fifteen years, and some for only three months, with an average for all roads of about two years. Various estimates of the increase of trains handled under this method were given, ranging from 10 to 43 per cent., with a probable average of 15 per cent.

Two methods of making the rating naturally suggest themselves, viz: (1) the practical method, by trying, on the controlling part of each division, what can be pulled by each class of engine; and (2) the theoretical method, based on calculations from locomotive dimensions and physical characteristics of the road. Of the forty-three lines reporting to Mr. Henderson, twenty-two depended on experimental determinations, fourteen made theoretical ratings which were checked by actual trials, and six were content with a theoretical rating alone.

The most elaborate preparations for tests were reported by the Southern Pacific Company, as appears from a circular issued April, 1897,—"To insure uniformity in conducting experiments to determine tonnage rating."

First. The locomotives on each division were divided into classes, and from each class were selected representatives, which were weighed with coal and water ready for service.

Second. A sufficient number of fully loaded cars, preferably of twenty-five or thirty tons capacity, were selected, company shipments of coal, rails or gravel, being found convenient. A list was prepared, showing the position, by number, of each car in the train from head and rear end, and the gross weight, as well as the gross weight of the train from both ends, including the car in question.

Third. A train, of the estimated capacity of the locomotive to be tested, was assembled on a light or level grade, the train being followed by a second locomotive by which the number of cars was increased or diminished so as to keep the test locomotive loaded to its full capacity.

Fourth. Having determined the hauling capacity of one class of engines in every part of a division, the relative resistances of the

Answers to Circular of Inquiry of October 1, 1901.

| QUESTIONS. | Penna. Co. N. W. System. C. & P. Div. | Penna. Co. N. W. System. | C. C. C. & St. L. | Erie. | B. & O. | W. & L. E. | L. S. & M. S. | C. L. & W. |
|---|---|---|---|---|---|---|---|---|
| Are Trains on your Road made up in accordance with established schedules of Tonnage Rating, and since when have such schedules been in force? | Yes. | Yes. | Yes, Since 1895. | Yes, 4 or 5 years. | Yes, Since May, 1897. | Yes, Since June, 1900. | Yes, Since 1895. | Yes, Since 1896. |
| What share, if any, had the Civil Engineering Department in the preparation of such schedules? | None. | None. | None. | None. | None. | None. | None. | None. |
| Are your schedules based upon actual trials with trains in service, dynamometer tests, or theoretical deductions from profile and speed. | First from Profile Checked by Tests. | Actual Tests and some Dynamom'ter Checks. | Actual Tests. | Both. | Actual tests and some Dynamom'ter Checks. | Actual Tests. | Actual Tests. | Actual tests Theoretic Ratings for comp'n. |
| Have you constructed Momentum Profiles for all or part of your mileage? | No. | For some Divisions. | No. | No. | No. | No. | No. | No. |
| What supervision is exercised to secure full loading of Engines? | Y. Master's daily rep't to T. Masters. | Y. M. sched'le Trains loaded under dir'ns of T. M. | T. M. Check daily tonnage reports of Trains. | Close supervision by Dispatcher and Sup't. | Checked by Dispatcher and Gen'l Sup't. | Conductors' Yd. Masters' Reports to C. S. Agent. | Check on Tonnage and Train-haul. | |
| What allowance in Train Resistance is made in favor of empty Cars? | 3 to 9 Tons per Car. | Factor depends on av. w't, speed, rul'g Grade. | No Ruling. | Rating – 6 (Act-Min.) number of Cars. | | Trains of Emp. not > 65 cars when not < 90% rat'g. Mix. tr'ns 5 to 10% Allow'e | None 65 Cars the limit. | 3 and 5 Tons. |
| Charts or Blanks? | Bulletin of Rating. | Bulletin of Rating. | | Bulletin of Rating | | | | Bulletin of Rating. |
| Unit. | Tons. | | Tons. | M's. | M's. | Tons. | Tons. | Tons. |

test train at different points are known, and the ratio of capacity of other classes may be determined by fewer tests. Particular attention was given to hard pulls in getting out of sidings or in pulling out of stations. Tests were made only at points where a single engine handles the entire train.

Fifth. Whenever practicable, tests were made: (1) to determine the maximum load with which the locomotive could start; (2) to determine the load that can be taken over a grade when it is approached at ordinary speed.

The rest of this circular is devoted to specimen reports of tests, which need not be repeated here. On theoretical determination Mr. Henderson quotes Mr. Tweedy, Chief Engineer of the Wisconsin Central Lines, as saying, "I am convinced that if some one would take sufficient time and pay enough attention to the matter, it would not be very hard to get up a table that would be so accurate that every part of a road could be rated theoretically in the office from the track profile, and in such a manner that the results would be practically satisfactory."

As a matter of local interest, I have the following information received in answer to questions addressed to the Engineering Departments of roads entering Cleveland, under date of October 1, 1901. (See table, page 57.)

An examination of this table shows that all the roads in this vicinity are using the tonnage rating; that this rating is generally determined by the Transportation Department by actual tests; and that therefore little or no work has been done on momentum or virtual profiles for these lines. Bulletins of rating, issued for the guidance of yard and train men, were the only forms furnished. The variety of methods for allowing for empty cars would seem to leave something to be desired in the way of a simple excess load formula.

In theoretical determination the factors are as follows:

First. Power of the locomotive. $T = \frac{pd^2s}{D}$

Limited (1) by mean effective steam pressure;

(2) by adhesion to rails.

Second. Resistance of the train. (1) Results of experiment and analysis best shown by Crawford's Curves. (2) As affected by proportion of empty cars.

Third. Value of momentum.

Fourth. Allowance for climatic and specific conditions.

At high speeds the effective steam pressure in locomotive cylinders is much below boiler pressure. For any considerable

range of speed the mean effective pressure can be experimentally determined only on the machines themselves, or the tractive power at different speeds measured by dynamometer. For the present discussion it will be assumed that this information is at hand. As ratings are generally required for freight service only, and are often limited by long ruling grades, this information is not always essential.

This pressure remains approximately constant at a piston speed below 265 ft. per second, corresponding to 10 miles per hour for an engine of 26″ stroke and 55″ drivers; and, in the Master Mechanics' reports for this year, is taken at 80 per cent. of the boiler pressure the same as in 1898. This reduces the formula for tractive power to $T = \frac{0.8\ pd^2s}{D}$ for single expansion engines, or, for 2-cylinder compounds, to $T = \frac{0.8\ pd_1^2s}{D\ (r+1)}$, where $d_1$ is diameter of the low-pressure cylinder and r is the ratio of cylinder volumes.

The value of T thus obtained is limited in any case by the adhesion of the drivers to rails. This is taken at 25 per cent. of weight on drivers with sand and most favorable conditions, and at 21 per cent. without sand.

Train Resistance, as affected by speed, has been studied with great care by many investigators, and an admirable comparison of the results of their labors is made on the accompanying diagram of 22 Train Resistance Formulæ by John G. Crawford, published in *Engineering News* for October 31, 1901. An examination of these curves reveals the greatest discrepancies at the higher speeds, running from 25 to 75 miles per hour and applicable to passenger service only.

Each of these formulæ is limited in its application, and all of them are carried beyond their limits on this diagram. For instance, none of the curves shows the high starting resistance, amounting to about 18 pounds per ton at speed zero, which will be mentioned later in this paper.

Mr. Crawford limits the application of his own formulæ to speeds between 25 and 75 miles per hour, which was the range of his experiments. Most of the other formulæ were determined within a much smaller range.

The tendency of the modern formulæ is toward lower values, which should be expected from improvements in rolling stock and roadbed. The Searles and Wellington curves are much too high on high speeds. The Wellington Eng. News and Baldwin formulæ

are practically the same up to 15 miles per hour, as appears best in the substituted values as follows:

| | Speed, in miles per hour. | Resistance, in pounds per ton. 10 | 15 | 20 |
|---|---|---|---|---|
| Wellington (Drop test, cars only) | $R = \frac{V^2}{130} + 4$ | 4.77 | 5.73 | 7.07 |
| Eng. News (All Resist) | $R = \frac{V}{4} + 2$ | 4.50 | 5.75 | 7.00 |
| Baldwin ( " " ) | $R = \frac{V}{6} + 3$ | 4.67 | 5.50 | 6.33 |

These resistances are in pounds per ton corresponding to velocities in miles per hour. For higher speeds the Engineering News formula gives values between those of the other two formulæ. Note that the Wellington formula was derived by drop tests, and the Baldwin Locomotive Works formula from indicator cards taken on a Vauclain 4-cylinder compound locomotive.

As to the effect of empty cars on train resistance, there seems to be much difference of opinion, and little uniformity of ruling as to ratings, as shown on replies to our circular. The addition of an arbitrary allowance seems to be as fair as Mr. Tait's elaborate scheme of equivalent tonnage based on a ratio of $\frac{1}{3}$, or two tons of contents to one ton of tare weight, though his suggestion of the value of statistics of fuel consumption and performance based on equivalent ton mileage have some value. The question is met most fairly by Mr. Henderson's formula for percentage of excess, in which $E = \frac{1.8}{y+6}$ where y is the resistance due to grade; and which is based on the results of experiments showing that an empty car has about 1.8 pounds per ton greater resistance than a loaded car at slow speeds. Y, the resistance due to grade (which should be compensated for curvature), is 20 times the rate per cent. of grade.

The value of momentum as a factor in rating is disputed. The difficulty of eliminating the necessity for stops on grades, and the always present probability that they may occur and stall an engine loaded to a momentum rating, have disposed many railway officers to the opinion that no reliance should be placed upon it. Mr. Vaughan advises that no allowance be made where the total rise of the grade exceeds 100 to 120 feet. However, an understanding of the advantage of momentum would emphasize in the mind of every engineer the importance of avoiding curves, tanks, etc., at the bottom of dips.

In general, it is well to remark, that the maximum rating for a locomotive over a certain division is not always, nor even often, its economic rating; and that expensive and dangerous risks are taken

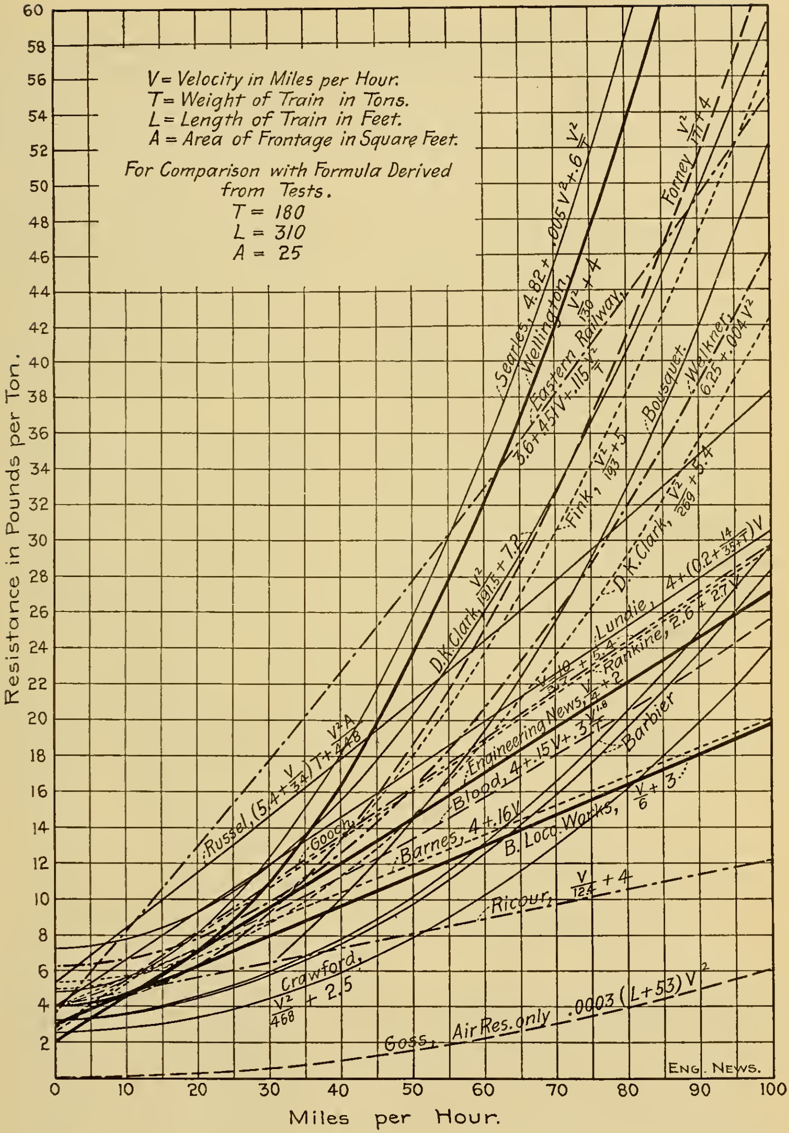


FIG. 1. *COMPARATIVE DIAGRAM OF TRAIN RESISTANCE CURVES REPRESENTING VARIOUS FORMULAS.

Of the above curves the following are mentioned by Mr. John B. Blood in the *Street Railway Journal*, of May, 1899; Searles' formula of $4.82 + .005\ V^2 + .6 \frac{V^2}{T}$ is the formula given in this article reduced by Mr. Blood to include only resistance of cars. The Eastern Railway formula is for speeds ranging from 43 to 50 miles per hour. Welkner's curve was derived at low speeds. Rankine's formula, $R = 2.6 + .27\ V$, and Blood's are given in the above-mentioned article.

Upper Barbier curve is drawn as published in the *Railroad Gazette*. The lower curve was reduced from the original formula by Ristine and Crawford.

The curve marked Bousquet was drawn from a table of resistance published a few years ago.

The curve marked Barnes, $R = 4 + .16\ V$, is one attributed to him and is not drawn from the accompanying table.

*Cut loaned by *Engineering News*.

as the result of stalling on grades, or backing up to take a run at them. However, the experimental ratings on the Cleveland, Lorain and Western Railway are so uniformly in excess of the theoretic ratings, in which no momentum allowance was made, as to make it appear that practically velocity is depended upon to a considerable extent.

The ordinary method of allowing for momentum is to deduct the velocity head from the total ascent, illustrated by Mr. Vaughn as follows: Suppose 5000 feet of 1 per cent. grade could be approached at a speed of 30 miles per hour or with velocity head of ($h = 0.0355V^2$) 32 feet. The total rise of the grade would be 50 feet, of which 32 feet would be overcome by the velocity head, leaving 12 feet through which the train must be raised by the engine. A rise of 12 feet in 50 stations would represent a 0.24 per cent. grade, and this grade resistance, added to the train resistance, would represent the work to be performed by the locomotive. The objection to this solution is that no allowance is made for the reduced tractive power and increased train resistance at the initial speed. Mr. Henderson meets this difficulty in his 1898 report by the use of the formula

$$S = \frac{70\ V^2}{yg + ysm - tm.}$$

Where S is the space traversed, V the speed in miles per hour, yg the resistance due to grade, $y_{sm}$ the mean resistance due to speed, and $t_m =$

$$\frac{\text{average tractive force}}{\text{weight of train.}}$$

Solved for the train load, this formula becomes

$$\text{Weight of train in tons} = \frac{\text{average tractive force (in pounds)}}{yg + ysm - \dfrac{70\ V^2}{S.}}$$

As the engineer is generally concerned with "S," or the possible length of the velocity grade, I would prefer the graphic solution proposed by Mr. E. H. McHenry, of the Northern Pacific Railway, in his little book of Engineering Rules and Instructions. I take the liberty of reproducing here a page from his book which is self-explanatory.

Enough has been said to illustrate the principles governing the determination of locomotive ratings. It remains to consider (1st), the form in which the work is got up; and (2d), the shape in which it is presented for the government of yard masters and trainmen.

In their 1901 Report the Master Mechanics seem to have committed themselves to the platting of curves. It is stated that,

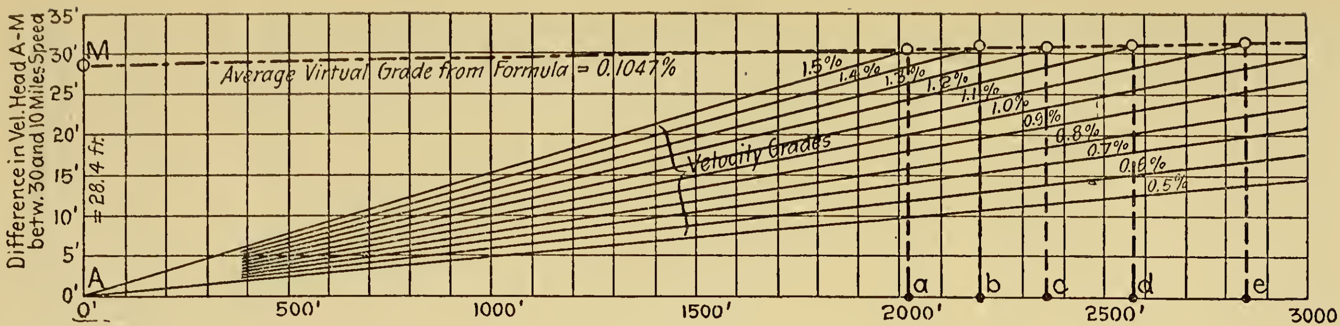


Fig. 2.

Formula for Determining the Average Virtual Grade.

$$S_v = \frac{1}{20}\left\{\frac{T}{W} - R\right\}. \qquad (1)$$

$S_v$ = average virtual grade expressed in per cent.
T = mean cylinder tractive power in pounds for given initial and terminal speed.
W = weight of train in tons of 2000 pounds, including engine and tender.
R = mean train resistance in pounds per ton of train.

Note.—The maximum virtual grade for a given trainload (W) is found by inserting in above formula the train resistance (R) and the cylinder tractive power (T) for minimum speed (10 miles per hour).

Example: In above diagram is shown the length of velocity grades for Engine Class D 3 Mogul, pulling a train weighing 1,250 tons (including engine and tender) for an initial speed of 30 miles and a terminal speed of 10 miles per hour.

Table of Mean Train Resistance in Pounds per Ton for Loaded Cars.

| Speed Initial. | Speed Terminal. | R. |
|---|---|---|
| 45 | 10 | 10.6 |
| 40 | 10 | 9.4 |
| 35 | 10 | 8.3 |
| 30 | 10 | 7.3 |
| 25 | 10 | 6.5 |
| 20 | 10 | 5.8 |
| 15 | 10 | 5.2 |
| 10 | 10 | 4.7 |

The difference in velocity heads (A M) taken from Table of Velocity Heads = 31.95 — 3.55 = 28.4 feet.

The average virtual grade ($S_v$) is calculated from formula:

$$S_v = \frac{1}{20}\left\{\frac{T}{W} - R\right\} = \frac{1}{20}\left\{\frac{11,473}{1250} - 7.3\right\} = 0.1047\%.$$

T = 11,743, taken from table of mean cylinder tractive power.
R = 7.3, taken from table of mean train resistance.

The length of velocity grades from A to a, b, c, d, e, etc., is found by construction, as shown in the above diagram, or may be found by calculation from the formula

$$l = \frac{d}{S - S_v},$$ in which l = length in stations of 100 feet;

d = difference in velocity heads for the given initial and terminal speed; S = actual grade in per cent., and $S_v$ = virtual grade, as found from formula (1). The maximum virtual grade of the above example is

$$= \frac{1}{20}\left\{\frac{17,850}{1250} - 4.7\right\} = 0.479\%.$$

Table of Velocity Heads.

(Vel. head = 0.0355 $v^2$.)
v = speed in miles per hour.

| Speed in miles pr hr. | Velocity head in ft. | Speed in miles pr hr. | Velocity head in ft. |
|---|---|---|---|
| 10 | 3.55 | 28 | 27.83 |
| 11 | 4.30 | 29 | 29.86 |
| 12 | 5.11 | 30 | 31.95 |
| 13 | 6.00 | 31 | 34.12 |
| 14 | 6.96 | 32 | 36.35 |
| 15 | 7.99 | 33 | 38.66 |
| 16 | 9.09 | 34 | 41.04 |
| 17 | 10.26 | 35 | 43.49 |
| 18 | 11.50 | 36 | 46.01 |
| 19 | 12.82 | 37 | 48.60 |
| 20 | 14.20 | 38 | 51.26 |
| 21 | 15.67 | 39 | 54.00 |
| 22 | 17.19 | 40 | 56.80 |
| 23 | 18.79 | 41 | 59.68 |
| 24 | 20.46 | 42 | 62.62 |
| 25 | 22.20 | 43 | 65.64 |
| 26 | 24.00 | 44 | 68.73 |
| 27 | 25.88 | 45 | 71.89 |

whereas in one instance it took 6 men 10 days to rate 13 classes of engines over 1500 miles of road without considering momentum grades, by the method suggested an ordinary division of say 500 miles can be rated in from 3 to 5 hours—after the diagrams are prepared, I suppose. This series of curves is as follows:

1. Dynamometer chart.

2. Relative and average tractive force.

3. Train resistance.

4. Energy of retardations to 5 miles per hour.

5, 6, 7. Dead and passing loads for class R engine at speeds of approach of 15, 25 and 35 miles per hour, respectively.

8. Relative engine loading—giving tons back of tender at different tractive powers.

9. Chicago and Northwestern Railway. Diagram of locomotive lading, ordinates, tonnage. Ratings published for Class R engines only, and reduced by this diagram.

10. Speed load diagram.

While these diagrams would facilitate office work greatly, it seems that rating bulletins to employes should be in figures, and, if separate ratings for each class are not published, then the scheme suggested by Thos. Tait, Mgr. Central Pacific Railway, before the New York Railroad Club, in January of this year, seems preferable. He would classify engines according to their haulage capacity by percentages, the standard class being taken as the 100 per cent. locomotive, and other 75, 80 or 120 per cent., as the case might be. Then, with the class letters of all locomotives lettered plainly on them, say on the cylinder head or cab, it would be possible for any official to know at once, from a glance at the train book, whether that engine was loaded to its capacity or not. As a method of supervising full loading of engines in the direction of the balance of tonnage, Mr. Tait would debit each Division Superintendent each day with the potential tonnage of his motive power over the ruling grade, and credit him with the tonnage actually moved. If an engine doubles, or is assisted over the heaviest grade, the next heaviest made with single engine is basis of the debit. Fast and local freights are usually charged with 90 per cent. of ordinary rating.

I have not discussed at length the elaborate report on locomotive tonnage rating on the Pacific System, Southern Pacific Company, published in November, 1900, by the Amer. Ry. Eng. & M. of W. Association, in which the officials of that line seem to have gone to the theoretical extreme, as distinguished from the expensive tests outlined at the beginning of the paper. Their method

includes some assumptions which have been strongly condemned; for instance, that heavily loaded trains on steep grades should attain a speed of 10 miles per hour in 2000 feet. Their rating table for standard locomotives, tabulating separately the different factors of train resistance, and rating for all possible grades ascending and descending is unsurpassed in detail, and their coefficients for transforming rating of the standard class, based on ratio of piston stroke to diameter of driver, and calculated for simple and compound locomotives, is unique.

Finally, it should be remembered that all roads must vary train loads to suit unusual conditions of weather and track. The authority to make this variation generally rests with the Chief Dispatcher. Our road has a scale of 7 lettered ratings, made by arbitrary deductions from the standard. Of these, the maximum or M rating is in force about 65 per cent. of the time, the N rating, 40 tons less, 15 per cent.; the O rating, 80 tons less than M, 10 per cent.; and the P, Q and R ratings, together, 10 per cent. of the time. Conductors show rate handled, and between what stations, on their wheel reports.

The bearing of the principles of locomotive rating upon the projection of railroad improvements is well discussed in a paper entitled the Economics of Railway Improvements, by W. W. Colpitts, read before the Canadian Society of Civil Engineers, October 24, 1901. The author calls attention to the advantage of grade reduction, as compared with double tracking, or reduction of distance or curvature. The reduction of a ruling gradient from 1 per cent. to 0.4 per cent. practically doubles the haulage capacity of locomotives, reducing the number of freight trains 50 per cent., and the expense of operating 25 per cent. As an element in the design of momentum grades, an analysis is made of train resistance at the point of starting, and the proper compensation for stations on ruling grades, the results of which are given in the following table:

| Ruling Grade of Line..... | 0.50 | | 0.75 | | 1.00 | | 1.25 | | 1.50 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Allowable Grade at Stop.. | 0.02 | | 0.31 | | 0.60 | | 0.88 | | 1.15 | |
| Min. Allowable Speed. | Dist. ft. | Time sec. | Dist. ft. | Time sec. | Dist. ft. | Time sec. | Dist. ft. | Time sec. | Dist. ft. | Time sec. |
| 7 Miles per Hour | 353 | 67 | 375 | 71 | 392 | 75 | 407 | 77 | 417 | 79 |
| 10 Miles per Hour | 763 | 100 | 834 | 108 | 909 | 116 | 991 | 124 | 1064 | 130 |

From this it would appear that, with a ruling grade of 0.5 per cent., and a minimum allowable speed of 10 miles per hour, a train of 65 cars would require a practically level station grade of the

train length + 763 feet or 3423 feet. Where the train is required to stop after leaving a siding, to permit of closing the switch, this distance would have to be doubled.

In discussing the advantage of reduction of rise and fall, on a basis of 85 cents per train mile, the following results are obtained:

A ruling grade of 0.5 per cent. or less is assumed not to exceed the angle of repose, and the rise and fall is not considered to effect appreciably the ordinary cost of operation and is estimated at 24 cents per foot per daily train per year. On grades of 0.5 per cent. to 0.8 per cent. the estimate is at 71 cents if on minor grade, or $1.42 if on ruling grade. On grades greater than 0.8 per cent., too long for momemtum grades, $2.27 to $2.98 is estimated.

In conclusion, Mr. Colpitts proposes, for the computations of the economic improvements, a form which is very suggestive. The items are carried out in dollars and cents for the present and proposed line, with the difference in parallel columns; those for grades, rating and time being estimated separately for trains in both directions. The list is as follows:

| | Present Line. | Propose Line. | Difference | Yearly Value. |
|---|---|---|---|---|
| Effect of Distance on Operating Expenses.......... | | | | |
| " " " " Passenger Receipts........... | | | | |
| " " " " Freight " ........... | | | | |
| " " Actual Grade.................................. | | | | |
| " " Virtual " ................................ | | | | |
| " on Rating of Class Locomotives.........Tons | | | | |
| " of Rise and Fall, on Maximum Grade, Feet | | | | |
| " " " " Medium " " | | | | |
| " " " " Minimum " " | | | | |
| " " Curvature..............................Degrees | | | | |
| Time Saved by Passenger Trains............Minutes | | | | |
| " " " Freight " ............ " | | | | |
| Improvement in Alignment .............................. | | | | |
| Total Yearly Saving in Favor of Improvement | | | | |

## DESCRIPTION AND THEORY OF CORADI'S ROLLING BALL PLANIMETER.

J. W. Beardsley, Member Detroit Engineering Society.

[Read before the Society, December 20, 1901.*]

In all problems, derived results cannot be of a degree of accuracy higher than the data upon which they are based. Such accuracy may be attained in general, by the use of diagrams furnishing graphical solutions, by the use of the slide rule and its modifications, and by the use of calculating machines, planimeters, integrators, etc. If this paper shall extend the use of one of these time and labor saving instruments, its purpose will be fulfilled.

Mr. Chas. E. Emery, in a paper on "The Polar Planimeter," Trans. Am. Soc. M. E., 1885, states,—"The term planimeter was first applied to an instrument invented by a Mr. Oppenkoffer in 1827. The instrument was improved by a Swiss engineer, M. Welty, in 1849, and in 1854 the now well-known polar planimeter was invented by Prof. J. Amsler, of Schaffhausen, Switzerland."

By another authority the invention of the polar planimeter is credited to John Lang, of Kirkcaldy, December 24, 1851, and in the earlier history the name platometer is also used.

The polar planimeter may be described as an instrument consisting of two arms, one of which rotates about a fixed point, the pole, and is hinged at its free end to the second arm which carries at one end the tracer point and at the other the recording mechanism.

Considerable literature exists describing many types and improvements of planimeters. With few exceptions, their types, whether for general or special use, are modifications of Amsler's polar planimeter, and consist of detailed refinements, leading up to the so-called precision, suspended and suspended ball planimeters, and to the latest type, Coradi's rolling ball planimeter.

A few of the more complete articles in current publications on the polar planimeter follow:—

"On the Mechanical Calculation of Earthworks," etc., by Clemens Herschel, *Journal of Franklin Institute,* April, 1874.

"The Polar Planimeter," by Chas. E. Emery, Trans. Am. Soc. M. E., 1885, also "A Novel Application of the Polar Planimeter," by the same author in the Trans. Am. Soc. C. E., Vol. 18, 1888.

"The Rolling Planimeter," by F. H. Reitz, Scientific Am. Sup., April 25, 1885.

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*Manuscript received January 27, 1902.—Secretary, Ass'n of Eng. Socs.

"Directions as to the use and a thorough Testing of Coradi's Planimeter," translated by J. S. Elliott, *Van Nostrand's Engineering Magazine,* June, 1885.

"The Polar Planimeter; its use in Practice," by Wm. Cox, *Engineering News,* March 21, 1891.

Keuffel & Esser Co. publish a manual, "The Polar Planimeter," by the same author.

"Some Observations on the use of Polar Planimeter," by Walter W. Patch, *Engineering News,* April 13, 1899.

Annual Report of the Chief of Engineers, U. S. Army, 1893, p. 1991, contains a description of the Coradi Rolling Planimeter, by H. M. Marshall, Asst. Engineer.

"Theory of the Polar Planimeter," by Fred Brooks, Journal of the Asso. Soc. of Engineers, Vol. III, p. 174.

The planimeter furnishes a correct method of rapidly determining plane irregular areas, such as areas of plotted sections

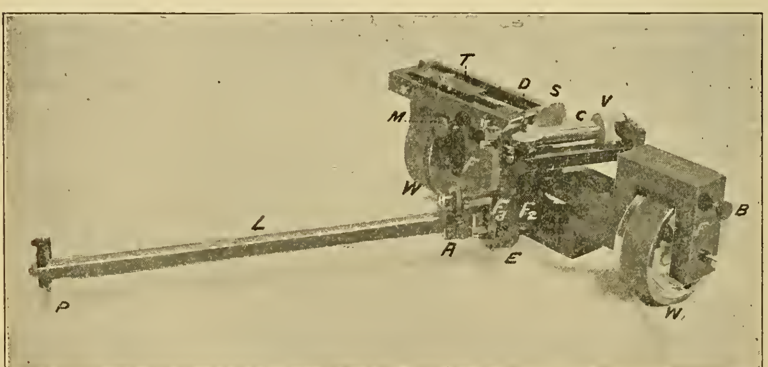


Fig. 1.

and profiles, acreage of land, indicator, diagrams, etc. It will mechanically add consecutive areas and express results in any desired denomination. Its results can be corrected for a known expansion or contraction of paper, but, unfortunately, not for errors in original notes and in platting.

The various forms of the polar planimeter are limited to small areas, and, although theoretically correct, the probable error of results derived with them is comparatively large. The rolling planimeter controls an area of width equal to the length of the tracer arm, and of indefinite length. Its uniform results entitle it to be classed as an instrument of precision.

Briefly, the instrument consists of a roller, supporting a frame which carries the recording apparatus, and from which is suspended

the tracing arm. The instrument rests on three points, viz, the two roller wheels and the tracer point.

The roller consists of an axle, at the ends of which two broad wheels, W and $W_1$, are rigidly attached. These wheels have equal diameters and milled faces, and one of them, W, which may be termed the drive wheel, has a finely toothed depression.

At the extremities of the roller axis the frame, F, is supported by pivot bearings. It carries two small frames. The spherical segment is attached to one, $F_1$, of these frames, and the tracer arm is carried by the other, $F_2$, to which is also pivoted the frame, $F_3$, carrying the cylinder and recording apparatus. The forward foot of this frame is pivoted on a stirrup attached to $F_2$, by means of which parallelism between the cylinder and tracer arm may be obtained. A shaft, parallel to the roller axis, carries at one end a toothed wheel, T, which engages with the similarly toothed depression on the drive wheel, and at the other end the spherical segment, S. The recording apparatus consists of a cylinder, C, having its axis parallel to the tracer arm and in the horizontal plane of the axis of the spherical segment; one end is enlarged and graduated to read by means of the vernier, V, to 0.001 of a revolution, and a screw gear at the other end turns a graduated disk, D, which records up to 50 complete revolutions of the cylinder. The vernier, V, must not touch and impede the motion of the cylinder, which is driven by friction contact with the spherical segment against which it is lightly held by a spring. The surfaces of the spherical segment and of the cylinder are highly polished. They are composed of a hard alloy. It is essential that these curved surfaces shall be true, that their axis shall be in the same plane, that the axis of the cylinder be parallel to the tracer arm, and that the roller wheels shall be true and of the same diameter.

The tracer arm, L, is graduated from 100 to 1100, the unit being 0.5 millimeter; these divisions are read to 0.1 by means of a vernier. A tangent screw, A, permits an accurate setting, and a binding screw, easily accessible when the tracer arm is swung to the right, holds it rigidly in the main frame. Its maximum length is about 0.5 meter, and it has a motion of about 30° each side of its zero or base line.

It is evident that the construction of the instrument is such that when the tracer arm coincides with the base line, no motion is imparted to the cylinder by the rotation of the spherical segment; also that, when the tracer arm is swung sidewise, without moving the roller, the cylinder is not rotated.

DIRECTIONS FOR USING THE INSTRUMENT.

Upon removing the instrument from its case, it should be noted, in order:

First. That the brake screw, B, clamping one of the drive wheels is loosened and that the roller moves freely.

Second. That the tracer arm is set at the desired reading and secured by the rear clamping screw. In case the lengthened arm is to be used, the connection should be made without removing the short arm from its socket.

Third. That the wheel, T, on the shaft of the spherical segment is carefully lowered by means of the cam screw, M, so that it properly engages with the roller drive wheel.

Fourth. That the frame, $F_3$, carrying the cylinder, is slowly released by means of the screw, E, so that the cylinder and the spherical segment have a free contact in all positions of the tracer arm.

Fifth. That especially the faces of the roller wheels and the surfaces over which they are to pass, the toothed wheels, and the polished surfaces of the spherical segment and cylinder are free from dirt and dust.

The instrument is then ready for use.

A simple rule for determining the setting of the tracer arm, the instrument being in adjustment, is, to set the arm at the known area of a plat carefully drawn to the required scale, trace clockwise this known area, note the difference between initial and final readings, reset the tracer arm at this reading or difference in readings and retrace the area. The reading should then give the known area in terms of the units desired. This rule depends upon equation, 4, which follows, and assumes that the tracer point coincides with the zero of the tracer arm graduation.

A card showing tracer arm settings for certain scales accompanies the instrument and gives the following general rules:—

"Trace steadily and uniformly. The surface of the spherical disk and cylinder must be kept clean and free from dust. Great care should be taken to prevent the cylinder from striking the spherical disk, and when not in use the chamois cushion should be placed between the segment and the cylinder. Long, narrow diagrams should be placed somewhat obliquely to the axis of the instrument.

The following additional rules may be useful:—

First. Use a smooth level table, and secure the paper containing the diagram to be traced against slipping or creeping.

Second. So adjust the tracer point by means of its bearing

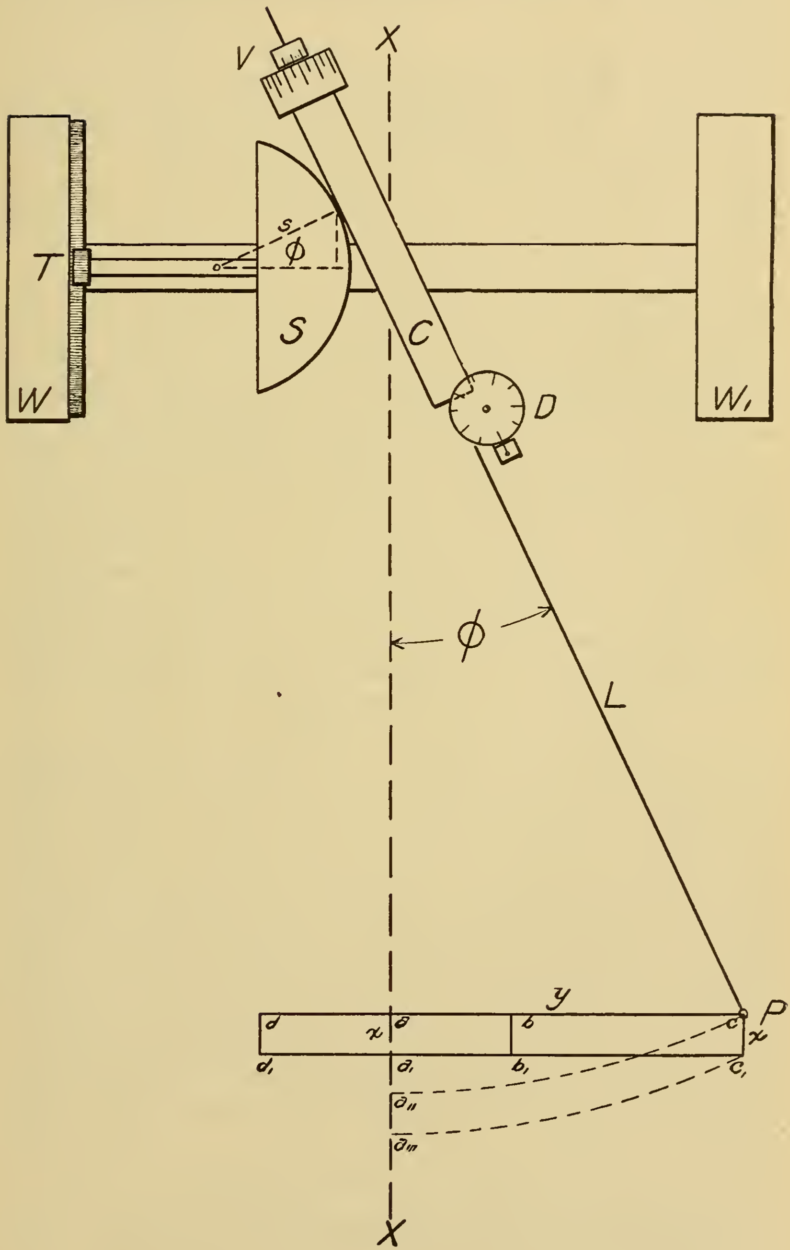


FIG. 2

post that it will not touch or cut slightly elevated portions of the drawing.

Third. Note that the spherical segment is firm on its axis, and that the cylinder does not touch its vernier.

Fourth. Place the instrument so that its base line passes somewhat centrally through the diagram to be traced.

Fifth. Take a point near base line for the initial or starting point.

Sixth. Trace all areas freehand.

Theoretically, the operations of the instrument are very simple.

Fig. 2 shows in plan the essential parts of the instrument; W and $W_1$, are the roller wheels; T, the small toothed wheel, engaging with the drive wheel W, and turning the spherical segment S; the graduations on the cylinder C are shown at its upper end, and the recording disk D at its lower end. The arrows indicate the relative motion of the upper portions of the moving parts.

Let the radii of W, T, S and C be w, t, s and c, respectively; X-X the base line with which the tracer arm L makes the angle $\Phi$, and a-c, the elementary rectangle, the area of which is to be determined in terms of an instrumental constant, length of tracer arm, and revolution of the recording cylinder or readings.

It will be observed that for a forward motion of the tracer point P, over the line $cc_1$, which $=$ x, a point on the circumference of W and of T passes through the same distance (radius of the toothed depression assumed the same as W for convenience); that the revolutions of T and S are equal, that a normal at the point of contact between the spherical segment and the cylinder makes an angle $\Phi$ with axis of the segment, also that no readings are given by tracing the line $aa_1$; that readings resulting from tracing line ac, equals $c_1\, a_{11}$, equals y, annul each other, being zero if traced on the arcs $a_{11}c$ and $c\, a_{11}$ respectively, bounding a figure of equal area, and that the area of the given rectangle having one side on the base line may be represented by readings obtained from tracing the line $c\, c_1$ equals x, hence:—

Number of revolutions of T and S $= \dfrac{x}{2\,\pi\, t}$

Radius of point of contact between S and C $=$ s sin $\Phi$

Distance traveled by point of contact $= \dfrac{s \sin \Phi}{t}$ x, and;

Number of revolutions of C, or Reading, $=$ R, $= \dfrac{s \sin \Phi}{2\,\pi\, tc}$ x

Therefore:—

$$x = \frac{2\pi tc}{s \sin\Phi} R \qquad (1)$$

$$y = L \sin \Phi \qquad (2)$$

and the required area of the rectangle is:—

$$xy, = \frac{2\pi tc}{s} L R, = fLR \qquad (3)$$

Or, the required area is represented by the product of an instrumental constant, f, into the length of the tracer arm, into the readings obtained.

Similarly the areas of rectangles b-$c_1$, or d-$c_1$, are determined, the areas a-$b_1$ and d-$a_1$ being mechanically subtracted from or added to the area a-c, respectively. Any area may be considered as the summation of a series of rectangles whose widths are very small and parallel to the base line X-X, and whose lengths are limited by the perimeter of the area given.

Equations (1) and (3) show that the readings are proportional directly to sin $\Phi$ and inversely to the length of tracer arm, or:

$$L_1 = R_1 L \qquad (4)$$

A steel testing scale accompanies the instrument. It is about 4 inches long, and is graduated by small depressions or prick points into inches and centimeters, and has a needle point at its zero. To test the instrument, set the tracer arm at any convenient length, raise or remove the bearing post at the end of the tracer arm, letting the tracer point rest in the desired graduation of the scale, and making the initial position of the free end of the scale near the base line, carefully rotate the scale about its zero point without side pressure through one or more complete revolutions. Reverse the motion, and note the difference between initial and final readings, which should agree if the instrument is in adjustment. This test should be made centrally and near the limit of the field, on each side of the base line. In general, all bearings are of the socket and pivot type, and are provided with steel screw and brass binding screw for adjusting the longitudinal movement of the various shafts.

From the theory and construction of the instrument it is evident that the axis of the cylinder must lie in the intersection of the horizontal and vertical planes through the spherical segment and the tracer arm respectively, and that:—

First. If readings obtained from tracing the same area are larger on the right side of the field than on the left, the necessary adjustment is made by moving the forward end of the cylinder to the left by means of the pivoted stirrup, and conversely. This adjustment is the only one that can be made by the operator, as the instrument is now constructed.

Second. If a minus reading is obtained by swinging the tracer arm to the right, roller wheels fixed, it indicates that the forward end of the cylinder is low.

Third. If a minus reading is obtained by tracing the base line, it indicates that the axis of the cylinder is below the intersections of the horizontal and vertical planes referred to above.

Unless the zero of the tracer arm graduations is coincident with the tracer point, the graduations, G, do not indicate the length of tracer arm, L, but are subject to a correction, e, or:—

$$L = G + e \qquad (5)$$

Theoretically, the value of e should be constant. Practically it varies slightly for different lengths of arm, and includes errors of graduation, etc.

Tracer arm settings, for determining areas drawn to any scale in terms of any desired unit, may be readily computed by equations (3), (4) and (5). Computed settings should be tested, and, if necessary, corrected by equation (4).

The following tabulation shows results derived from a series of tests with instrument No. 1428. Tables marked C give the mean of a series of continuous revolutions. Tables I to V, inclusive, involved the use of the test scale, while tables VI to VIII, inclusive, were free hand tracings. The area traced in Table I was located centrally with respect to the base line, in Table II at the extreme right, and in Table III at the extreme left of the field.

Table VIII shows the final, corrected tracer arm setting to be used in tracing areas platted to the scale 1 inch = 100 ft., and to give reading in terms of 0.005 acres.

| Table. | Setting of Arm. | Mean of Readings. | | Probable Error. | | Relative Error. | | Area Tracer, Sq. In. |
|---|---|---|---|---|---|---|---|---|
| | | Plus. | Minus. | Plus. | Minus. | Plus. | Minus. | |
| I A | 1000.0 | 927.61 | 928.40 | 0.120 | 0.057 | $\frac{1}{7730}$ | $\frac{1}{16280}$ | 28.274 |
| I C | 1000.0 | 927.46 | 928.36 | ...... | ...... | ...... | ...... | 28.274 |
| II A | 1000.0 | 928 34 | 928.90 | 0.029 | 0.033 | $\frac{1}{32010}$ | $\frac{1}{28150}$ | 28.274 |
| II C | 1000.0 | 928.29 | 928.51 | ...... | ...... | ...... | ...... | 28.274 |
| III A | 1000.0 | 927.40 | 928.33 | 0.021 | 0.041 | $\frac{1}{44160}$ | $\frac{1}{22640}$ | 28.274 |
| III C | 1000.0 | 927.27 | 928.00 | ...... | ...... | ...... | ...... | 28.274 |
| IV A | 500.0 | 1861.24 | 1861.14 | 0.044 | 0.020 | $\frac{1}{42300}$ | $\frac{1}{93060}$ | 28.274 |
| C | 500.0 | 1861.37 | 1861.21 | ...... | ...... | ...... | ...... | 28.274 |
| V A | 649.1 | 1432.24 | 1432.59 | 0.046 | 0.048 | $\frac{1}{31140}$ | $\frac{1}{29840}$ | 28.274 |
| C | 649.1 | 1432.24 | 1432.53 | 0.046 | 0.048 | ...... | ...... | 28.274 |
| VI | 1000.0 | 1431.37 | 1431.16 | 0.20 | 0.19 | $\frac{1}{7160}$ | $\frac{1}{7530}$ | 43.56 |
| VII | 715.6 | 2004.19 | 2004.94 | 0.38 | 0.45 | $\frac{1}{5270}$ | $\frac{1}{4460}$ | 43.56 |
| VIII | 717.2 | 2000.12 | 2000.26 | 0.26 | 0.39 | $\frac{1}{7690}$ | $\frac{1}{5130}$ | 43.56 |

In testing instrument No. 1182, readings obtained on the right and on the left side of the field were practically equal and indicated that the instrument was in good adjustment. Accidentally, it was observed that readings obtained at the center of the field were very large. A more detailed test was made, using a tracer arm setting of 520.0, and the 1-inch point on the test scale, the zero of the scale being set successively, 1, 2, 3 and 4 inches from the base, and on both the right and the left sides. Five continuous plus revolutions of the test scale were made and the reading noted, and similar minus readings were taken.

The results indicate a possible flattening of the spherical segment near its pole, or a decrease in the diameter of the cylinder near its middle. The required adjustment was regarded as one proper to be made by the instrument maker. Table I is a detailed tabulation of these data, and Table Ia is a summary of them.

TABLE I.

| Test Scale, Zero Point. | Readings. | | Differences. | | | Mean. | Difference. |
|---|---|---|---|---|---|---|---|
| | Plus. | Minus. | Plus. | Minus. | + ∾ — | | |
| 4″ R. | 971.9 | 973.9 | ...... | ...... | — 2.0 | 972.9 | ...... |
| ...... | ...... | ...... | — 0.4 | — 0.3 | ...... | ...... | — 0.35 |
| 3″ R. | 971.5 | 973.6 | ...... | ...... | — 2.1 | 972.55 | ...... |
| ...... | ...... | ...... | — 4.4 | — 2.3 | ...... | ...... | — 3.35 |
| 2″ R. | 967.1 | 971.3 | ...... | ...... | — 4.2 | 969.2 | ...... |
| ...... | ...... | ...... | — 1.6 | — 0.5 | ...... | ...... | — 1.05 |
| 1″ R. | 965.5 | 970.8 | ...... | ...... | — 5.3 | 968.15 | ...... |
| ...... | ...... | ...... | + 24.5 | + 26.7 | ...... | ...... | + 25.60 |
| Base Line | 990.0 | 997.5 | ...... | ...... | — 7.5 | 993.75 | ...... |
| ...... | ...... | ...... | — 28.0 | — 28.1 | ...... | ...... | — 28.05 |
| 1″ L. | 962.0 | 969.4 | ...... | ...... | — 7.4 | 965.7 | ...... |
| ...... | ...... | ...... | + 5.3 | + 4.0 | ...... | ...... | + 4.65 |
| 2″ L. | 967.3 | 973.4 | ...... | ...... | — 6.1 | 970.35 | ...... |
| ...... | ...... | ...... | + 4.9 | + 2.6 | ...... | ...... | + 3.75 |
| 3″ L. | 972.2 | 976.0 | ...... | ...... | — 3.8 | 974.1 | ...... |
| ...... | ...... | ...... | + 0.5 | — 0.8 | ...... | ...... | — 0.15 |
| 4″ L. | 972.7 | 975.2 | ...... | ...... | — 2.5 | 973.95 | ...... |

TABLE I A.

| Test Scale, Zero Point. | Mean Readings. | Difference. |
|---|---|---|
| 4″ R. and L. | 973.42 | ...... |
| | ...... | — 0.10 |
| 3″ R. and L. | 973.32 | ...... |
| | ...... | — 3.55 |
| 2″ R. and L. | 969.77 | ...... |
| | ...... | — 2.85 |
| 1″ R. and L. | 966.92 | ...... |
| | ...... | + 26.83 |
| Base Line | 993.75 | ...... |

A determination of the accuracy of the instrument was made as follows: The tracer arm was set at 520.0, five continuous plus revolutions of the test scale were made, and the reading of each revolution was noted, for the areas indicated in the following tabulation, Table II. Two areas were traced free hand. The results illustrate the general principles that the absolute error is approximately constant, the relative error is proportional to the area traced, and freehand tracing is subject to an error two or three times greater than the error obtained by using the test scale.

## TABLE II.

### Traced by Means of Test Scale.

| Area, Square Inch. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.1416. | | | 12.5664. | | | 28 2740. | | | 50.2655. | | |
| Reading. | v. | $v^2$. | Reading. | v. | $v^2$. | Reading. | v. | $v^2$. | Reading. | v. | $v^2$. |
| 198.1 | 0.04 | 0.0016 | 781.3 | 0.26 | 0.0676 | 1755.1 | 0.14 | 0.0196 | 3117.6 | 0.26 | 0.0676 |
| 198.2 | .06 | .0036 | 781.5 | .06 | .0036 | 1755.3 | .06 | .0036 | 3117.1 | .24 | .0576 |
| 198.1 | .04 | .0016 | 781.9 | .34 | .1156 | 1755.3 | .06 | .0036 | 3117.4 | .06 | .0036 |
| 198.2 | .06 | .0036 | 781.5 | .06 | .0036 | 1755.3 | .06 | .0036 | 3117.5 | .16 | .0256 |
| 198 1 | .04 | .0016 | 781.6 | .04 | .0016 | 1755.2 | .04 | .0016 | 3117.1 | .24 | .0576 |
| Mean read'g | | 198.14 | | | 781.56 | | | 1755.24 | | | 3117.34 |
| $(\Sigma v^2)^{1/2}$ | | 0.110 | | | 0.438 | | | 0.179 | | | 0.460 |
| r | | 0.04 | | | 0.15 | | | 0.06 | | | 0.15 |
| $r_0$ | | 0.02 | | | 0.07 | | | 0.03 | | | 0.07 |
| Error, sq. in | | 0.0003 | | | 0.0011 | | | 0.0005 | | | 0.0011 |
| Relat'e error | | 1/9900 | | | 1/11,200 | | | 1/58,500 | | | 1/44,500 |

### Traced Freehand.

| Area, Square Inch. | | | | | |
|---|---|---|---|---|---|
| 12.5664. | | | 78.5398. | | |
| Reading. | v. | $v^2$. | Reading. | v. | $v^2$. |
| 777.9 | 0.14 | 0.0196 | 4861.7 | 0.48 | 0.2304 |
| 777.5 | 0.54 | .2916 | 4862.5 | .32 | .1024 |
| 778.4 | 0.36 | .1296 | 4863.1 | .92 | .8464 |
| 777.7 | 0.34 | .1156 | 4862.0 | .18 | .0324 |
| 778.7 | 0.66 | .4356 | 4861.6 | .58 | .3364 |
| Mean reading... 778.04 | | | | 4862 18 | |
| $(\Sigma v^2)^{1/2}$ | | 0.996 | | | 1.244 |
| r | | 0.34 | | | 0.42 |
| $r_0$ | | 0.15 | | | 0.19 |
| Error, square inch | | 0.0024 | | | 0.0031 |
| Relative error | | 1/5,200 | | | 1/25,600 |

Table III shows data taken from the card accompanying instrument No. 1182. The value of e is computed in terms of tracer arm graduations, and is assumed to be identical for adjacent settings. Limited data for determining e were obtained by means of the test scale, using the 1-inch point, the zero 1 inch to the right of the base for an arm setting of 260, 520, 780 and 1040, also the 2-inch point, having the zero of the scale 2 inches to the right of the base line for 520, and similarly the 3-inch and 4-inch points, 3 inches and 4 inches to the right, for 780 and 1040, respectively. The readings and reductions are shown in Table III, and the derived values show the importance of testing computed tracer arm settings.

The operation of the instrument would be simplified if the tracer arm were carefully graduated to correspond to the actual length of arm.

TABLE III.

| Scale. | Arm Setting. | L. | e. |
|---|---|---|---|
| 1″ = 100′ | 964.6 | $6G + e$ | − 5.0 |
| 1″ = 100′ | 803.0 | $5G + e$ | + 1.0 |
| 1″ = 50′ | 642.6 | $4G + e$ | + 1.5 |
| 1″ = 40′ | 402.2 | $2\frac{1}{2}G + e$ | |
| ...... | ...... | ...... | + 1.2 |
| 1″ = 100′ | 322.0 | $2G + e$ | + 1.5 |
| 1″ = 40′ | 201.8 | $1\frac{1}{4}G + e$ | + 1.4 |
| 1″ = 100′ | 161.7 | $G + e$ | |

| Arm Setting. | Area Traced, Square Inches. | | | | Value from Prop'l Area. |
|---|---|---|---|---|---|
| | 3.1416. | 12.5664. | 28.2740. | 50.2655. | |
| 260 | 1940.0 | | | | 1940.00 |
| 520 | 969.2 | 3854.8 | | | 966.50 |
| 780 | 646.0 | | 5804.5 | | 646.18 |
| 1040 | 481.8 | | | 7726.4 | 483.72 |

EQUATIONS:

$$2G + e = (G + e)\frac{1940}{966.5} = (G + e)\ 2.007;\quad e = \frac{-1.82}{1.007} = -1.8$$

$$3G + e = (2G + e)\frac{966.5}{646.18} = (2G + e)\ 1.496;\quad e = \frac{2.08}{0.496} = 4.2$$

$$4G + e = (3G + e)\frac{646.18}{483.72} = (3G + e)\ 1.336;\quad e = \frac{-2.08}{0.336} = -6.2$$

# TIDAL SCOUR IN HARBORS, OR THE FUNCTION OF TIDAL BASINS WITH SPECIAL REFERENCE TO THE HARBOR OF BOSTON.

By Joseph P. Frizell, Member Boston Society of Civil Engineers.

[Read before the Society, February 5, 1902.*]

The position of Boston as a great commercial city depends solely upon its harbor. The original establishment of a great city here was due to the circumstance that this situation affords singular facilities for transferring goods and passengers from the vehicles suited to traverse the land to the vehicles suited to traverse the sea, and *vice versa*. This made Boston a center for the exchange of products between the adjacent country and remoter countries, and although the interests of the city have in the process of time become greatly diversified and combined with others not distinctly commercial, and although the entire obliteration of the harbor would still leave the city in possession of immense manufacturing and monetary interests and great interests in domestic trade, such an event would destroy its distinctive character as a commercial city. From an early period of the city's history the preservation of the harbor has been an object of profound solicitude to those interested in the city's welfare.

It is no part of the purpose of this paper to enter into a history of Boston Harbor; still less to undertake a detailed exposition of the principles of harbor construction and maintenance. I propose only to direct your attention to a single phase of the latter topic which has been the subject of an immense amount of discussion, and which, in my poor opinion, has never, so far as I am aware, been presented in its true scientific aspect.

The several engineering commissions, both civil and military, which have examined and reported upon the harbor of Boston have, with perfect truth and propriety, laid great stress upon the efficiency of tidal scour in maintaining the channels of the harbor, and have insisted as a cardinal principle of harbor conservation upon the preservation in unimpaired volume of the estuaries and basins which contribute to the tidal currents through the channels of the harbor. These statements have been reiterated till the belief has become firmly fixed in the public mind that the tidal basins are absolutely essential to the preservation of the harbor, and that any impairment of capacity in the former must be directly followed by a corresponding injury to the latter.

The general proposition that tidal basins create currents through the channels of the harbor and so contribute to the main-

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tenance of depth in the latter, and that a diminution in the volume of the former would in time be followed by an abatement of depth in the latter, if other means were not resorted to for maintaining the depth, is one that I have no disposition to controvert. What I undertake to say is that this proposition has limitations which it is necessary to bear in mind if we would attain to a correct comprehension of the matter. Although it is very easy to maintain the general statement that tidal basins tend to the maintenance of tidal channels, the engineering mind naturally reverts to the question: What is the precise amount and value of this tendency? Might not other means of maintaining the depth be advantageously employed? Is it worth while to hold, for this purpose, many thousand acres of land susceptible of valuable uses? Is the function performed by this area as a tidal basin valuable enough to warrant its permanent appropriation to that use?

Of late years much disposition has been manifested to press the latter question in connection with projected works of improvement. Yet to my mind the arguments on which the negative is maintained appear no more rational than those used in the affirmative. It is said, for instance, that, by reason of the numerous *dams* on the streams dicharging into the harbor, there is no longer any sediment brought in, at least none of a character to affect the harbor injuriously. It is quite true that the contributions of these streams, deleterious to the harbor, have been checked, and for many years almost wholly suspended, through the agency of these dams. It is for this reason that tampering with the tidal basins has not been followed immediately by any injurious effects. Let us examine this point more attentively.

The matters brought down by a river are of two kinds: First. Fine sediment held in suspension by the water. This is brought down in times of high water, when the current is but slightly checked by the dams, and the latter have but a slight influence upon the quantity of sediment. Second. Heavier and coarser materials rolled or pushed along the bottom. The former is so light that a current considerably diminished by curtailment of the tidal basins would still have power to prevent its accumulation in the channels. It settles in the shallower parts, where the velocity is checked by the diminished depth. Materials of the latter class are arrested by the dams. The heavier matters come to rest near the head of the pond, where they form a shoal which gradually extends upstream. The lighter matters accumulate in the mill pond. None of this matter is annihilated or withdrawn from the stream. It simply rests and accumulates and awaits developments. When the dam is carried

away, as almost inevitably happens in the course of a generation, not only the sedimentary accumulations of years, but much matter derived from the dam itself goes down the stream. The same result occurs when the dam is removed for rebuilding and high water intervenes. Even should the dam prove to be absolutely permanent, the pond will be filled till the drift in high water passes freely over the dam to the next pond below.

It will be seen, therefore, that these dams are no permanent security against the invasion of the harbor by drift. They may delay for many years the progress of the drift, and they are liable to precipitate it into the harbor in great masses, instead of the regular contributions of free and open streams; but all the drift carried by the stream, except possibly in the case of a perfectly permanent dam, sooner or later reaches the harbor, and in the more common case the mass of drift is considerably augmented by the dams themselves.

It may be worth while here to advert to a possible event which might have the gravest consequences for Boston harbor. Its probability is certainly remote, but we must remember that the dangers which threaten works of engineering are most commonly those which appear remote; obvious and manifest dangers are usually foreseen and guarded against. The headwaters of Charles River afford sites for extensive storage reservoirs. The construction of such a reservoir in the interest of water power or water supply is a thing to be expected. The failure of such a reservoir is an event entirely within the range of possibility. The failure of such a reservoir, holding a billion or more of cubic feet, might, among other deplorable consequences, bring hundreds of thousands of cubic yards of *débris* into the harbor.

The direct action of waves on the shores and islands of the outer harbor creates great volumes of drift, which is strewed over the bottom by the tidal currents. Efforts have been in progress for many years to arrest this agency by artificial defenses on the headlands most exposed to the action of waves. But affluent streams and waves are not the only means by which drift is brought into harbors. Shoaling is often caused by sand brought by littoral currents, thrown upon the shore by the action of waves and borne inland by winds.

This action has been very conspicuous on the western shore of Lake Erie. The improvement of the port of Grand Haven, at the mouth of Grand River, has been greatly complicated by this phenomenon. This improvement was undertaken by the method usually adopted in such cases, viz, the construction of converging

jetties at the mouth of the stream, the jetties, in this case, extending to the 20-foot contour of the lake. The river, near its mouth, pursues its course for some distance nearly parallel to the lake shore, and here immense volumes of sand are blown in. With a drainage area of 5300 square miles, the river has a volume capable of maintaining a depth of 20 feet; but, owing to the influx of sand, the greatest depth attained, after an expenditure of $750,000, is 17 feet.

The entrance to Coos Bay on the Pacific coast also presents this feature and extensive works in the form of sand fences and plantations have been undertaken to check influx of sand.

The quantity of sand that can be carried inland from the coast, where conditions of wind and tide are favorable, is astonishing. At the Golden Gate Park, near San Francisco, where this agency is active, the Park Commissioners report the influx at 800 cubic feet per annum for each linear foot of shore line. The coast of France, from the mouth of the Adour to the mouth of the Garonne, a distance of 150 miles, is exposed to this action, which has already covered some 300,000 acres of ground, in some instances to a depth of 300 feet, changing the course of streams, creating ponds and marshes, and bringing untold evils upon the agricultural population. The same agency is active on the coasts of Denmark and of the Baltic provinces of Prussia.

There is no reason, of course, to apprehend the influx of sand in Boston Harbor upon the titanic scale above mentioned; but it must nevertheless be conceded that, so long as there are sandy beaches on the shores of the harbor, and sandy flats bare at half tide, the influx of sand through the agency of wind is a factor not to be ignored. Sand will naturally be carried from the beaches and flats to the deeper parts, and, unless the agencies for its removal are present, will accumulate there and cause shoaling.

Action now in progress at Ipswich, on the north shore of Massachusetts Bay, has in it a suggestion of possible danger to Boston Harbor. Points near the lighthouse, where, within the memory of persons now living, vessels rode at anchor, are now 80 rods from tidewater. Sand dunes now cover grounds where 20 or 30 years ago were orchards and fruitful fields. It is understood that this is a comparatively recent development, unknown in the early history of the town. The causes of such phenomena are obscure. Accretion or erosion at one point of a shore line occasions changes at other points, the nature and extent of which it is impossible to predict. If action of this sporadic kind is liable to arise at any point of the shore line of Massachusetts Bay, then no

harbor can be considered entirely free from liability to such irruptions of sand.

I think, therefore, that the tidal basins cannot be dispensed with on the ground that tendencies to shoaling are no longer to be expected in the harbor. If they are dispensed with, it must be upon other grounds.

We will now proceed to indicate the true reasons why the tidal basins are no longer of any material use in the conservation of the harbor. Imagine a tidal basin where the ebb and flow reaches ten feet or thereabouts, separated from the open sea by some miles of flats, covered a foot or two at low water. If the surface of the flats were at an absolutely uniform level, no channel would ever be formed. Such uniformity, however, never occurs in nature. There will be some one path across the flats which the water will follow more easily than any other. In this path the swiftest velocity will establish itself and erosion will be most active. Every accession of depth increases the volume of water traversing the channel and consequently increases the erosion. The movement, once inaugurated, must persist, because the increase of the effect strengthens the cause. At first view it is not easy to understand how the flux and reflux of the tide can operate to form a distinct channel. One would be apt to suppose that it would simply move the material to and fro, and that the ebb tide would leave a particle where the flood tide found it. The ebb tide is not the reciprocal of the flood tide, neither does the same water follow the channel from end to end. Water charged with sediment finds itself crowded out of the channel, and, taking a slower movement in the shallower parts, deposits its burden. The process of erosion, therefore, consists in raising material from the channel and spreading it over the general surface of the flats. Where the tidal basin is the estuary of a stream, the ebb tide is stronger than the flood tide and the eroded material has a general tendency seaward.

If the tidal basin were of indefinite extent, this process of deepening would go on indefinitely. But, under ordinary natural conditions, the channel would soon reach the state in which all natural tidal channels find themselves, viz, a condition of maximum depth, a condition of equilibrium between the scouring power of the current and the resisting power of the ground. This cannot be otherwise. The forces to which these channels owe their origin and existence have acted through the immeasurable periods of geological time. The channels have attained such dimensions that the forces tending to enlarge them are in exact equilibrium with the forces tending to diminish them. The tendency to erosion is ex-

actly balanced by the tendency to deposit. In the supposed case of an incipient channel across the tidal flats the condition is one of unstable equilibrium, in which any change tends to increase itself. The case of the completed channel is one of stable equilibrium, in which any change of dimensions tends to correct itself. This condition is more sharply defined than we are apt to suppose. Suppose such a channel to filled up to three-quarters of its former cross-section. The velocity, at or near low tide, is increased to four-thirds of its former value, and the scouring power, being as the square of the velocity, is nearly doubled. The channel must very soon return to its former dimensions. On the other hand suppose the cross-section to be increased by one-third. This reduces the velocity to three-quarters of its former value and the scouring power to not much more than one-half. Now the current has not only no power to deepen the channel, but no power to prevent its silting up; and, in the natural course of things, we might look, at no distant day, for a return to its former dimensions.

Lieut.-Col. Geo. L. Gillespie, of the Corps of Engineers, stated, in his report of 1888 on Boston Harbor, that the main ship channel, before dredging, had a depth of 18 feet at low tide and a width of 100 feet. For purposes of comparison we will assume the effective width at 500 feet. Compare such a channel with the channel now in course of execution for Boston Harbor, viz, 30 feet deep and 1200 feet wide at low tide. The cross-section of the latter is to that of the former as four to one. The erosive power, with the same volume of water passing at each tide, is as one to sixteen. That is to say, assuming the capacity of the tidal basins to have remained unaltered from the foundation of the city, the erosive power of the current is reduced to one-sixteenth of its original value,—*i.e.,* for all practical purposes, obliterated. By opening such a channel you have disclaimed the aid of the tidal basins. You have laid a task upon them which they are entirely inadequate to perform, and you must thenceforth dispense with their aid. It must be understood that the above comparison, of a channel 500 feet wide and 18 feet deep with a channel 1200 feet wide and 30 feet deep does not strictly, or even approximately, represent the conditions of scour in Boston Harbor, because these dimensions refer to the contour lines of the channels, while there are large areas outside these lines which take part in the movement. These figures are used as the best available illustration of the effect of dredging.

I hold that there is no principle in engineering more indisputable than this: When tidal channels are materially enlarged

by dredging, the tidal forces are no longer adequate to extend them or to maintain them. They must be thenceforth maintained by the means used for their extension.

Before the enlargement of the channels by dredging, the tidal basins were properly regarded as the primary factor in the conservation of the harbor. Henceforth they must be regarded as only a secondary and feeble aid to the operation of dredging, an operation which, once taken up, can never be laid aside. Let us endeavor to get some idea of the value of the basins for that use, and for this purpose direct our attention to the basin which it is proposed to isolate from the harbor by means of the Charles River dam. To this end we will ascertain the quantity of earth which a given amount of water power may be expected to remove, and the cost of doing the same work by means of the dredge.

Mr. E. L. Corthell, in his "History of the South Pass Jetties," page 213, says that the current of the Mississippi removed from the bar at the South Pass in four years 3,283,123 cubic yards of earth. The South Pass, before its improvement, probably took about one-fifth of the flow of the Mississippi; after its improvement about two-fifths. We may, therefore, assume an average of three-tenths of the average volume going through the pass during the improvement. We take the average flow of the Mississippi at 750,000 cubic feet per second, three-tenth of which is 225,000 cubic feet. We have no very definite information as to the head under which this water acted. It is stated that when Grand Bayou, a channel leading from the South Pass to the Gulf, was closed by a dam, the water on the upstream side of the dam stood 16 inches above that on the downstream side. In default of more definite information we will take 16 inches as the head under which the water acted in making this excavation, 225,000 cubic feet per second, acting under a head of 16 inches, represents 33,333 horse powers. 33,333 horse powers, acting for four years, carried away 3,283,123 cubic yards of earth, which was at the rate of about one-fifteenth of a cubic yard per diem per horse power.

The next question is: What was the cash value of this work? By the report of the Mississippi River Commission for 1899, tests of their dredges, "Beta," "Gamma," "Delta" and "Epsilon," showed a net cost of dredging, exclusive of towing, of less than one cent per cubic yard. Of course the annual cost of dredging, embracing towage, repairs, accidents and maintenance of crews while waiting for practicable stages of water, would be much higher. It appears to me, however, that where dredges are maintained, and where the only advantage derived from currents is a certain saving in cost

of dredging, we could not estimate the value of that saving higher than three cents per cubic yard. On this basis the value of a horse power, acting upon naked masses of earth without the intervention of any artificial organs, would be one-fifth of a cent a day, which is 73 cents a year.

The proposed pond on the Charles River is said to contain, at the proposed level, which is not far from average high tide, some 440,000,000 cubic feet. This is capable of maintaining, for six hours, a flow of 20,370 cubic feet per second. We may assume that the tidal currents are diminished by this quantity of water. According to observations of Mr. Henry Mitchell, made in November, 1863, the head acting to impart velocity to the water passing through the main ship channel of Boston Harbor, being the difference of level between the water at the Navy Yard and at the lower light, was 0.31 feet on the flood tide, and 0.43 on the ebb, the average being 0.37 feet. By the operation of this dam, therefore, the scouring power of the tide, acting in Boston Harbor, is diminished by 20,370 cubic feet of water per second, acting under a head of 0.37 feet. In other words by 837 horse power, which, according to what precedes, would have a cash value of $611 per annum.

While this figure might be increased or diminished by more exact data; while this cursory examination necessarily leaves out of view much that has important relations to the subject, and while it is still true that the tidal basins have a conservative tendency as regards the channels of the harbor, one thing appears certain from this inquiry: The importance of these basins has been greatly reduced by the enlargement of the channels, and they have now no such value as requires them to stand in the way of improvements essential to the welfare of the city.

## DISCUSSION.

Mr. F. W. Hodgdon.—Mr. Frizell, after describing the various ways in which material is brought into and deposited in a harbor, viz,—from the streams emptying into it and from the wearing away of islands and headlands exposed to the wash of the sea at the mouth of the harbor, finds that in Boston tidal basins cannot be dispensed with, on the ground that the tendencies to shoaling are no longer to be expected. Then he goes on to show that while originally the relations between the tidal basins and the channels of the harbor were such that the currents created by the ebb and flow of the tide maintained a navigable depth of 18 feet at mean low water, at the present time the relations are such, owing to the re-

duction of the tidal basins and the increase in the size of the channels from dredging, that the velocity of the currents is very much reduced and without artificial help would not be able to maintain the increased size of the channel.

The general proposition is true that the scouring effect of a current is reduced when the channel through which it flows is enlarged and thereby its velocity is reduced, and the velocity is also reduced when the volume of water which flows through a given channel in a given time is reduced, but in applying this proposition to Boston harbor many complications arise.

The volume of water has been reduced by the filling in of the flats and the sections of the channels have been enlarged by dredging. At the same time the sections of the channels have been reduced by the filling of the flats on their banks. This applies only to the harbor above Governor's Island. The dredging which has been done up to within the last two years in the lower harbor, being in the channels through which there is practically no current, the general direction of the current in these places being across the channel. The principal contraction of the channel in the upper harbor was brought about by the filling of the South Boston flats, which is a modification of the plan for a training wall along the southerly line of the ship channel recommended by the United States Commissioners on Boston Harbor, who examined the harbor and reported plans for its improvement during the years 1859 to 1866.

The channels in Mystic river and Charles river have been increased in depth by dredging and decreased in width by the filling which has taken place. In doing the work of dredging, the bottom is found to consist usually of a surface coating of silt of varying depth; under this is found blue and yellow clay with some sand and gravel, and in some sections rock is encountered. In general the material is quite hard and of such a character that it cannot be readily excavated by clam shell dredges such as are used in New York and other ports to the south of us. While visiting some of the English harbors I was very much struck by the character of the material composing their bottom, it being very different from that found in Boston. The range of the tide, as a rule, was very much greater than at Boston and the material of the bottom was usually a soft silt which was readily shifted back and forth by the tidal currents. In many cases the entrances to the docks were provided with sluices for discharging the water from the docks in such a way as to wash out the accumulations of silt on each tide, in order to be able to open and close the gates. The material seemed more like

the sludge which is taken from the tank sewers near the pumping station at Old Harbor than any material which we have in the bottom of our harbor.

There is one thing more in connection with the scouring effect of tidal currents which has been discussed to a considerable extent, and that is, that while the volume of water passing in and out on each tide is practically the same, yet the scouring effect is vastly greater on the ebb than on the flood. This is readily explained when one comes to consider that the space to be filled in the tidal stream increases rapidly as the tide rises, the banks sloping up from low water mark to high water mark, so that on the flood tide the greatest volume has to flow in when the cross-section at the mouth of the river is greatest, while as the water drains out from the basins up the river, the slope being the other way, the volume as the tide falls has to pass out through a smaller cross-section, creating much larger velocities and therefore causes much greater scouring effect. The increased volume caused by the fresh water flow of the tributaries to the harbor is but a small fraction of the tidal volume, and, therefore, gives but a very small increase to the scouring effect except in times of freshet.

Another element to be considered is that the scouring effect is very largely that of rolling material along the bottom of the stream rather than carrying it in suspension, and as the bottom has a general slope toward the mouth, the force required to move the material in that direction is much less than that required to move it up hill toward the land. The present velocity of the channels in Boston harbor is generally inside two miles an hour.

Recently I have had an opportunity of studying the scour of a channel which was excavated through the beach at Osterville in the town of Barnstable. The material there is ordinary beach sand, mixed with more or less gravel. The velocity through this channel often exceeds three miles per hour, and has scoured out the material and increased the depth to a considerable extent since the original excavation, the sand being washed out while the gravel remains to form a pavement on the bottom and retard further scouring. In this case the sides of the channel are formed by timber and stone jetties so that the total scouring force is expended upon the bottom. In this case the resultant scour is seaward, the material being deposited just beyond the end of the jetties where it is dispersed by the heavy waves created by the storms in Nantucket Sound, the depth of the channel being from three feet to five feet at low water.

Mr. J. P. Frizell.—I am not able to perceive the force of Mr. Hodgdon's reasoning in his attempt to demonstrate that the ebb tide is stronger than the flood tide, irrespective of affluent streams. It appears to me that during the flood tide the sea is higher than the basins by an amount sufficient to create the necessary current, and no more, and during the ebb is lower than the basins by a similar amount. This difference is greater near low tide than high tide on account of the diminished cross-section of the channels, but neither the difference of level nor the velocity created by it can be any greater on the ebb than on the corresponding stage of the flood.

The declivity of the ground would hardly have an appreciable effect. Suppose the ground to slope seaward one foot in a mile, and suppose a particle such that a single ebb or flood tide would give it a movement of 100 feet. Then the seaward force would exceed the landward by about $\frac{1}{5000}$ part, and the particle might be expected to make a seaward gain of $\frac{1}{50}$ of a foot, each tide being a mile in 25,000 tides, or say a mile in the course of 34 years.

Mr. G. T. Sampson.—The New Haven Railroad dock, No. 1, at South Boston, was dredged from 24 to 26 feet in 1882, and not again until last year. About 15,000 yards was taken up at that time of a black material, a sort of a fluid deposit which would move with the tide. This material could not all come from vessels or from the wash of adjoining yards. It seems as though some of it worked in from the harbor.

Mr. F. W. Hodgdon.—Large quantities of material are constantly being deposited in the harbor. Mr. Frizell spoke of the wind carrying sand from the shore and depositing it in a harbor. We have a case of this at Provincetown, where the sand is constantly being moved by the northwest winds; a portion of it is carried into the harbor and a portion is driven over the dunes and into the forests which are being buried. The Commonwealth is now engaged in covering these waste sand dunes with beach grass and other shrubs to prevent the wind from having an opportunity to move the sand. In Boston harbor dust is constantly being blown into the harbor; the sweepings from the wharves are dumped overboard and the docks which receive the greater portion of this material have to be frequently dredged to maintain their depth. In some of the docks sewers discharge, and with the sewage comes more or less of the sand washed from the streets in heavy showers.

While the dredges are working in the harbor the material is constantly being stirred up and a portion is carried by the currents and deposited at a greater or less distance from the dredge.

Near the mouth of the dock of which Mr. Sampson speaks the bottom of the harbor is a fine black sand, and as this is stirred up by the dredges considerable quantities are undoubtedly carried by the currents and deposited in the eddies formed near the mouth of the dock. There is also undoubtedly a very large amount of material dumped overboard from the docks and vessels, the same as at all other wharves, notwithstanding the care which is taken to prevent it.

## THE SULPHUR DEPOSITS OF CALCASIEU PARISH.

By Frank M. Kerr, Member Louisiana Engineering Society.

[Read before the Society, January 11, 1902.*]

Calcasieu Parish is situated in the southwestern part of our State, and has within the past year been brought prominently into notice by reason of its claims for recognition as a future oil field. Next to the Parish of Orleans, it is to-day the largest and wealthiest parish in the State, its area being nearly 3400 square miles; its resources, timber, rice, cotton, cane and minerals; its assessed valuation, upward of $13,000,000, and its population over 30,000. Enterprise, progress and enhancement of values have characterized its history for the past ten years, and, in my opinion, there appears just now no limit to the possibilities of its future, particularly in the field of sulphur and oil.

It is, however, with its possibilities in sulphur with which I feel more competent to speak, having, for about four years, between 1886 and 1890, been connected with a series of examinations and explorations instituted to verify statements previously advanced in regard to the mineral resources of a tract of land near the town of Sulphur, upon which the town of Florance and the extensive plant of the Union Sulphur Company is now situated.

The sulphur deposit was originally discovered about the year 1868 by an organization styled the Louisiana Petroleum and Oil Company while prospecting for oil which it had been encouraged to believe would be found in large quantities by boring sufficiently deep. This encouragement arose from surface indications in the form of "oil springs" found bubbling in many localities in the marshes, and the oil itself coating the water of the latter to such an extent that it was skimmed off and disposed of commercially by the natives as a lubricant.

The magnitude of the discovery made by the company is shown by the record of its boring, which was as follows:

| | Thickness. | Depth. |
|---|---|---|
| Yellow and blue clay | 160 | 160 |
| Gray and yellow sand | 173 | 333 |
| Rock | 2 | 335 |
| Blue sandy limestone | 48 | 383 |
| White crumbling limestone | 60 | 443 |
| Pure sulphur | 108 | 551 |
| Gypsum containing sulphur | 99 | 650 |

*Manuscript received February 17, 1902.—Secretary, Ass'n of Eng. Socs.

| | Thickness. | Depth. |
|---|---|---|
| Pure sulphur | 6 | 656 |
| Gypsum containing sulphur | 24 | 680 |
| Pure sulphur | 10 | 690 |
| Gypsum, containing large percentage of sulphur | 440 | 1,130 |
| Gypsum containing sulphur | 100 | 1,230 |

So great was the promise of riches from this discovery at the time, that the thought of oil was completely overshadowed and neglected, while every endeavor was centered upon devising means and methods for developing the apparent bonanza in sulphur.

The outcome of this was the organization of another company, known as the Calcasieu Sulphur and Mining Company, which, in due time, after further borings and explorations, made elaborate preparations for sinking a shaft, securing as its engineering adviser a French engineer named Granet, who had been recommended by the French Government. Buildings were erected and a large amount of material and machinery collected at the site, the latter being brought out from Belgium.

This was in 1873, before the advent of railroads in that section of the country, and when the only means of transportation was by way of schooners and barges to the coast, and thence by hauling to the interior.

The process adopted for sinking the shaft was that known as the "Kind and Chaudron." A copy of the contract and specifications for constructing this shaft I happen still to possess. It is quite a unique document, and expressed in a very foreign style, and would no doubt prove interesting reading to many of us; but owing to the length to which this *résumé* will, I fear, carry us, I will only say that it called for an outer wooden shaft to a depth of not less than 120 feet, with a diameter not less than 18 feet 8 inches in the clear, and an inner iron "extracting tube," as it was designated, reaching down into the sulphur bed to a point 462 feet below the surface of the ground, and it also laid great stress upon the character and construction of a "moss box" and the final resting place of the latter.

However, after two attempts to carry out this plan at points about 150 feet apart, in neither of which was the wooden shaft carried down more than about 100 feet and none of the "iron tubing" used, the effort was abandoned and the company failed.

The cause assigned for the abandonment of the plan was the difficulty of controlling the great body of water-bearing sand, which not only resisted the progress of the work, but from time to time overcame every effort to exclude it from the shaft itself.

Numerous spasmodic revivals of interest in the mines, as the locality was designated, occurred from time to time after that, but little beyond prospect boring was done until the period between 1886 and 1889, the heavy flow of sulphurous water and the presence of the great body of "shifting sand," as named by many, discouraging further effort.

In 1886, however, the National Sulphur Company came to the front and undertook to develop the mines. It was with this company that I was afforded the opportunity to personally satisfy myself in regard to the existence, extent and character of the sulphur deposits in Calcasieu, and I submit the following record of one of our borings to convey to you some idea of the subject, viz.:

| Feet from Surface. From | To | Thickness of Strata. | Material. |
|---|---|---|---|
| 0 | 167 | 167 | Blue and yellow clay. |
| 167 | 328 | 161 | Water-bearing sand. |
| 328 | 335 | 7 | Coarse sand. |
| 335 | 342 | 7 | Fine sand and gravel. |
| 342 | 345 | 3 | Gravel. |
| 345 | 346 | 1 | Clay shale. |
| 346 | 350 | 4 | White water shale. |
| 350 | 355 | 5 | White clay and sand. |
| 355 | 380 | 25 | White water spar. |
| 380 | 399 | 19 | Spar. |
| 399 | 400 | 1 | Sand. |
| 400 | 409 | 9 | Soft spar. |
| 409 | 428 | 19 | Soft white water marl and spar. |
| 428 | 436 | 8 | Sandy white marl. |
| 436 | 439 | 3 | Pure crystalline sulphur. |
| 439 | 445 | 6 | Lime and sulphur. |
| 445 | 450 | 5 | Pure crystalline sulphur. |
| 450 | 452 | 2 | Lime and sulphur. |
| 452 | 453 | 1 | Pure crystalline sulphur. |
| 453 | 463 | 10 | Lime and sulphur. |
| 463 | 469 | 6 | Pure crystalline sulphur. |
| 469 | 493 | 24 | Black lime and sulphur. |
| 493 | 498 | 5 | Lime and sulphur. |
| 498 | 500 | 2 | Pure crystalline sulphur. |
| 500 | 502 | 2 | Black lime and sulphur. |
| 502 | 516 | 14 | White lime and sulphur. |
| 516 | 520 | 4 | Pure crystalline sulphur. |
| 520 | 530 | 10 | Lime and sulphur. |
| 530 | 533 | 3 | Pure crystalline sulphur. |
| 533 | 541 | 8 | Lime and sulphur. |
| 541 | 543 | 2 | Pure crystalline sulphur. |
| 543 | 546 | 3 | Lime and sulphur. |
| 546 | 552 | 6 | Black lime and sulphur. |
| 552 | 563 | 11 | White lime and sulphur. |

| Feet from Surface. From | To | Thickness of Strata. | Material. |
|---|---|---|---|
| 563 | 570 | 7 | Porous lime and sulphur. |
| 570 | 574 | 4 | Lime. |
| 574 | 580 | 6 | Pure crystalline sulphur. |
| 580 | 586 | 6 | Lime and sulphur. |
| 586 | 603 | 17 | Black lime with traces of sulphur. |

In this depth you will observe that 32 feet of solid crystalline sulphur, practically pure, chemically, was found, and in the last 167 feet of the boring an aggregate of 77 per cent. pure sulphur.

This well was subsequently carried down 100 feet deeper, the same general character of the stratification maintaining.

A continuous flow of sulphurous water prevailed until the sulphur bed was reached, often spouting to a height half way up to the top of the derrick, and at times carrying large flecks of petroleum in considerable quantities. A considerable flow of oil also occurred at a depth of about 450 feet.

The cores which you see on the table before us were taken from this well. These cores, with a great number of others, were taken from the core barrel by myself. They are all that remain to me of quite a large collection; some five or six large boxes of cores were shipped to the company at the north, and have been lost sight of. The cores before us have suffered some from the lapse of time, handling and chipping, but it may nevertheless interest you to inspect them.

Having satisfied itself as to the extent and value of the sulphur deposit, this company in its turn proceeded to devise ways and means to extract it, and having the lessons taught by the failures and experiences of its predecessors by which to govern itself, proposed a new departure for this side of the water, at that time, in the process and method of sinking a shaft.

The following extract from a letter from Professor E. W. Hilgard, the eminent geologist, received by the National Sulphur Company, at the time, in response to its request for his opinion in regard to the extent of the deposit and the quality of the sulphur, further fortified the company in its estimate of the value of the inducement offered for the investment of capital.

Professor Hilgard wrote: "As to the extent of the deposit, the regularity of the limestone beds that overlie the sulphur affords every reason for the expectation that the sulphur deposits will be found to extend horizontally over a considerable area, to be expressed in square miles as units at the very least, if we consider the great thickness of the deposit.

"As to the quality of the sulphur and its merits, the fact that it is mineralogically identical with the Sicilian deposits, and by the simple operation of eliquation will furnish an article almost chemically pure, free from all impurities that give rise to so much inconvenience in connection with the use of sulphuric acid in the arts, speaks for itself."

The process proposed to be used by the National Sulphur Company in sinking its shaft was that known as the "Pœtsch Process," which aimed at carrying shafts, boreholes, or foundations of structures through water-bearing strata without pumping, by freezing the surrounding material and then making the desired excavation in the frozen mass as if it were rock, and seemed particularly adapted to the conditions prevailing at the mines in Calcasieu. The basis of the process is in the use of ammonia, which is first evaporated by heat from a boiler containing spirits of salammoniac (a solution of ammonia in water), then cooled in a condenser and reduced to a liquid state by a pressure of ten atmospheres, whereupon it is allowed suddenly to expand in a system of wide pipes passing through a cooling tank, from which the ammonia is finally pumped back to the original boiler.

The cold produced by the sudden evaporation of the ammonia is transmitted from the cooling tank down into the ground to be frozen by means of a solution containing one-third (by weight) chloride of calcium or chloride of magnesium, dissolved in two-thirds water, the freezing point of this solution being at 40 degrees Fahr.

In the cooling tank the solution is reduced to a temperature of — 4 degrees to — 13 degrees Fahrenheit, and then carried down into the soil by a system of vertical freezing pipes. These are arranged in pairs, one inside the other, the outside pipe being closed at the bottom, while the lower end of the smaller inside pipe is left open and furnished with side perforations, the object being to pass the cold solution down the inside pipe and force it to rise through the annular space between the two pipes.

A set of these double pipes is distributed around the circumference of the pit to be excavated and connected at the top with two pipes passing in horizontal rings clear around the space of the pit. One of these is the distributing pipe, forming the connection between the pumps and the small inner pipes, which are attached to it by a system of flexible lead pipes, making allowance for irregularities of position and furnished with stop-cocks.

The other is the collecting pipe which is similarly connected with the several large outside freezing pipes, and serve to pass

the used-out solution back to the cooling tank, the upper ends of the outside freezing pipes being closed with a stuffing box.

Thus there is a continual circuit with theoretically no less of material either in the ammonia or in the chloride of calcium. The influence of the freezing process extends to the water of the surrounding saturate deposit; this becomes solidified and is maintained so until material to the extent of the excavation required has been disposed of as so much solid matter and the excavation has been followed up by the walls of the shaft or other construction required.

Unfortunately the National Sulphur Company, through financial inability, never reached the period of construction with its project, and in the end also failed and abandoned the enterprise.

Its operations had, however, by this time attracted considerable attention to the locality, and it was not long before there was another Richmond in the field under the name of the American Sulphur Company, the year 1889 witnessing more prospect boring and investigations at its hands, in turn satisfying its promoters as to the extent and value of the deposit. Money this time seemed to be the least obstacle in the way, and soon new buildings, including a fully equipped foundry, and more material and machinery appeared on the ground; the town of Florance budded into life; a branch road was run out to it from the Southern Pacific, and under the able direction of the late Colonel R. P. Rothwell, Editor of the *Engineering and Mining Journal* of New York, a shaft was shortly started on its way down to the sulphur beds by the "shield process," Granet's second wooden shaft being selected as an entrance to the mine.

The principles and features of the "shield process" are too generally known to need description here.

In this instance, however, the route of the shield and its accompanying auxiliary work was downward in a vertical line instead of onward on horizontal lines as in previous successful operations. How much this fact was responsible for the ultimate result it is difficult for me to say. Nevertheless, in spite of the promise of success for the American Sulphur Company, which seemed assured, the operations at the mines being carried on apparently with intelligence and system, and reports of progress being favorable, it, too, had in turn to surrender to the force of circumstances, for one dark day operations ceased and it was soon learned that the shield had in some unaccountable way become detached from the shaft above, sunk out of reach in the

sand and the pit had filled up to the top with water, petroleum and sand. There was a resumption of work later on, the shaft being pumped out to near where the shield had gotten away, preparatory to letting down another shield; but this was never procured, and the next news of importance was to the effect that the American Sulphur Company had merged into the Union Sulphur Company.

To this company finally belongs the palm. It has succeeded, reaching the sulphur beds by a process which is the opposite of that which had been proposed by the National Sulphur Company, namely, by heat instead of cold.

This company dispenses with the use of shafts, and extracts the sulphur from its depths by a process devised by a Mr. Frasch and known as the "Frasch, or Hot Water Process."

Though I have twice visited this plant, I cannot claim any degree of familiarity with the details of its workings.

In general terms, however, water heated, I understand, to a temperature of 350 degrees Fahr. is injected down into the sulphur beds through pipes, kept under high pressure there, melting the sulphur and forcing it to the surface through other interior pipes, where it is conducted in its fluid state into shallow vats (about ½ foot deep), allowed to cool, and then broken up into fragments ready for shipment. The fragment on the table before us came from a vat into which I saw the sulphur run and cooled off.

This process is certainly, so far, the solution of the problem, and is being operated on a most extensive scale, tons upon tons of chemically pure sulphur being brought to the surface day after day and shipped to the markets of the world.

However, it seems clear to my mind that there is a limit to the extent to which the sulphur strata can be chambered by this process, or, rather, that the limit over which control can be exercised by it is circumscribed, and that it will be necessary to constantly change the base of operations for extracting the deposit, as I believe has proved to be the case in such operations as have so far been carried on.

At the time of my first visit to the plant there were but eight boilers in operation; when there again last April this number had been increased to sixteen, all equipped with oil-burning furnaces. Since then I understand that as many as thirty boilers are supplying hot water for the process, and that it is contemplated doubling this number at no distant day.

In conclusion I will say that I have burdened you with this crude sketch of some of the leading events and operations con-

nected with the development of a part of the sulphur field in Calcasieu, not upon any grounds of novelty in the methods so far pursued except possibly in the last instance named, but because I believe that the field is susceptible of and destined to further and far greater development, calling for the employment of other methods than those yet assayed or at present in use, to devise which will require the exercise of engineering ingenuity and skill of no mean order, and eventually prove food for thought for many of us.

Furthermore, if there be anything in signs, by which I mean the presence of well-established conditions analogous to those of other localities enthusing many of the commercial centers of the world to-day, Calcasieu is on the eve of establishing claims to another distinction—that of nursing beneath its sulphur deposits and limestone beds oil fields of large extent and superior quality; further opening up brilliant opportunities for engineering talent, not only in reaching and controlling the fluid, but in devising new and improved methods and appliances for its utilization as a prime economic in the world of motion, illumination and manufacture.

## OBITUARY.

### Thomas Laidlaw Raymond.

Member of the Louisiana Engineering Society.

Thomas Laidlaw Raymond, a native of New Orleans, was born in 1853 and died November 15, 1901.

He received a preliminary education in the schools of New Orleans, and in 1870 entered the University of Virginia, from which he graduated in 1874 with the degrees of civil and mechanical engineer.

His bent of mind and education prepared him to follow the profession of civil engineer. His first employments were, however, on educational and commercial works, with the Preot School and the firm of Elkin & Co.

In 1879 Mr. Raymond commenced his life work by entering the service of the Government as United States Assistant Engineer, and was successively stationed at the South Pass Jetties, in Florida, at Sabine Pass and on other works on the Gulf coast.

He was subsequently, for over eight years, connected with the State Board of Engineers, until, in 1897, he was chosen First Assistant Engineer of the Drainage Commission of New Orleans, which position he filled until the end of his life.

At the request of the Sewerage and Water Board, Mr. Raymond served as a member of their Advisory Council of Engineers. His interest in this work and the public welfare was so great that, in view of a legal doubt concerning his right of payment, these services were rendered gratuitously.

The duties of these several positions were discharged with an ability and fidelity which won for him the esteem of his employes and associates.

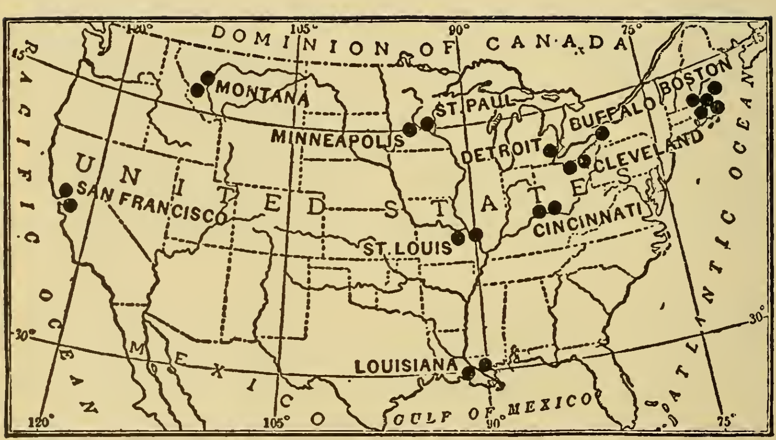
Mr. Raymond's success as an engineer was due partly to special fitness for such work, partly to close observation and application, and largely to a high standard of personal and professional duty. Combined with this equipment were a good heart and a generous manner, which secured the warm regard of all who had the privilege of serving with him. His associates

will all join in a recognition of ability as an engineer and his value as a citizen and friend.

Mr. Raymond was elected a member of the American Society of Civil Engineers in 1897. He was among the most active in organizing the Louisiana Engineering Society, and served as its second president in 1899. His work and interest continued unabated until his death.

Mr. Raymond married in 1889, and leaves a widow, a son and two daughters.

B. M. HARROD,
GEO. G. EARL,
M. P. ROBERTSON,
*Committee.*


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BOSTON
BUFFALO
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
GULF OF MEXICO
120°
105°
90°
75°
30°

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## COMPENSATION OF SKILLED LABOR.

BY J. RICHARDS, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, February 7, 1902.*]

IT may add to the interest of the remarks to be made here this evening to say that the author has spent more than twenty-five years of his life in organized works; is himself a practical workman in various branches of mechanical art, both in metal and wood work, and that more than twenty years of this time he was foreman, manager and owner of works, in direct contact with skilled men, directing their work and arranging compensation for the same.

This experience, under various systems of paying wages, has produced the views to be presented in this paper. Of course, attention has been given to writings on the subject, especially those of Dr. Brentano, a German scientific author, who is almost alone, or in advance at least, in showing the true measure of wages, and that the rate follows the personal product.

The last year of my shop experience was in England, under the contract system, in a company where I was a director and consulting engineer. I also acted as an arbitrator in some disputes that arose between the different departments or between the workmen and the owners.

The subject of skilled labor and wages is by no means a simple one. Its complexity arises from the rapidly changing conditions and relations of skilled industry during the last sixty years. It is a branch of social economics that has but little useful literature,

*Manuscript received February 18, 1902.—Secretary, Ass'n of Eng. Socs.

and, indeed, none at all that deals with the equities of the subject, unless it be in the current serial matter of the day, and that is almost never impartial.

Even the word "wages" lacks logical definition. Does it mean the money compensation for workmen's time, or does it mean compensation for work accomplished? These things are essentially different and require different terms to define them. The first is a "rate" of wages, while the second is the "amount" of wages. I beg that you will keep these terms in mind, because out of them and the relation between them must arise much that will be said of compensation.

The "amount" of wages, or compensation for work accomplished, is the labor cost that enters into commodities, and constitutes the real economic problem, the one that directly affects our industries and determines their success.

The "rate" of wages, or compensation for workmen's time, is a social rather than an economic problem, dealing with the intellect and skill of workmen, their ingenuity and power of producing; consequently it affects directly the workmen themselves.

The amount of wages is very uniform the world over when measured by product—indeed, must be so, as will appear—but the rate varies with the productive power of workmen.

It does not much matter to an employer whether it requires one, two or three workmen to produce a given result in a given time. He can as well pay the amount of wages to three men as to one man or two men. The amount of the wages, measured by production, is the matter he is directly interested in; but to the workmen the rate is a serious matter, directly affecting their social and other conditions, because it is a measure of their personal compensation.

Thirteen or more States have at this time "Bureaus of Labor Statistics" which every year publish voluminous reports, amounting collectively to between four and five thousand pages. We have also a "National Bureau of Labor Statistics," equipped with all required means of ascertaining facts respecting the rate and amount of wages, with all that concerns or belongs to the subject of labor. Voluminous statistics have been printed. One document of more than 850 pages, called "Young's Labor Statistics," was issued in 1876, and many editions of this have since appeared. In one place more than 50 pages were devoted to slave labor among the Egyptians and the Romans, and during the feudal ages in Europe, —almost an insult to modern skilled industry—but in no case, so far as I know, can anything be found bearing upon the relative

productiveness of labor, or upon the relation between the *rate* of wages and the *amount* of wages.

The first attempt in this country to distinguish between the "rate" and the "amount" of wages was made about 1887, when Mr. Schoenhof, of Paterson, N. J., was sent abroad, under a Commission from the Department of State, to investigate into the "amount of wages" or the labor cost of commodities in Europe. The facts gathered by him can be found in the Consular Reports of 1888; but the inquiry was suddenly abandoned for political reasons, and since that time it has not received much attention in a public way in this country; but it is safe to say that until the relation between the rate and amount of wages is understood and appreciated by both employers and workmen no solution of the present contention will be reached.

I myself had something to do with this matter. In 1886 the late Thomas G. Shearman, of New York, came to the works in England* to ascertain something concerning wages, and was amazed when I told him the wages could not be ascertained by the usual means, at least by the pay roll, because the work was contracted. He was a man of celebrity and of wide experience, and, at the time, a Federal officer, and had always considered the subject of wages as one of rate only. At my suggestion he visited several works in England, and, on his return home, induced the President to send out a special agent to investigate in Europe the amount of wages or the cost of the labor component in various commodities. His investigations covered steel rails, boots and shoes, woolen cloth, and perhaps other commodities, as can be seen in the Consular Reports before named, also in writings of Mr. Schoenhof that I am not able to cite at this time.

To arrive at the first stage of a practical application of this theory of wages, the following postulates will be assumed:

First. The costs of manufactured articles of every kind are made up of four elements or components; namely,—material, wages, expense and profit.

Second. All staple articles of manufacture, such as enter into the world's trade, must have a nearly uniform or international value.

Third. The amount of wages, entering into the cost of manufactured commodities, is also nearly uniform, and must be so, irrespective of the *rate* of wages paid for their production.

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*The Atlantic Works, Geo. Richards & Co. (Limited), owned principally in this country.

Fourth. The rate of wages depends upon what workmen produce, or upon efficiency of their labor and to some extent on artificial values.

Fifth. Fluctuations in the rate of wages are commonly a result of demand and supply.

Sixth. The amount of wages that can be paid to produce a commodity is not an accident, but is the result of fixed commercial laws of general operation, and upon the relation to other components.

Briefly expanding some of these postulates, the first one, relating to components, is merely an axiom, capable of proof by simple accounts. Profit, as a component, is just as essential as material, labor or expense. Without profit no industry can be carried on, and when the amount of profit is declared or known and is reasonable, it never leads to discontent or labor disturbances. A man so obtuse as not to know that profit is an essential component cannot be an intelligent mechanic.

The second postulate is also an axiom. Machinery, cotton cloth or any other commodity cannot have a difference of price in different markets except as affected by local taxes. For staple products of all kinds there is a "world's" price, which can vary within narrow limits only, and the range between these is constantly becoming narrower, as the price of commodities becomes more fixed in the neutral markets of the world; so obviously must the sum or value of the components be fixed. The aggregate must come out the same. If the cost of one component is raised, that of the other components must be lowered accordingly; and as material, expense and profit are approximately uniform, or should be, so also must the *amount* of wages be, but not the *rate* of wages. This may vary in any degree without disturbing the balance of components. The amount of wages in a watch must be the same in Waltham as it is in Geneva, although the rate of wages paid to workmen be as four to one, as was the case twenty years ago. The watches made in these places met and were sold in London and had to conform to a general price.

When the balance of these several components—material, labor, expense and profit—is lost, and their aggregate exceeds what we may call the general or world's value of the product, then the industry affected must either die or be moved to a new environment. Industry follows the line of least resistance, especially in these times when powerful combinations are indifferent to localities and when local or empirical skill has nearly disappeared in our industries.

I mentioned a general or world's value of products.* We are all the time coming nearer to such a standard for common commodities, and the fallacy of the demand and, in the same degree, the supply theory is becoming apparent. All commodities, including wages, have a natural value, measured by the cost of their production, and it seems strange that any one should think so important a matter as the general rate of wages could be governed by so transient a cause as demand and supply. It is, in fact, assuming that the rate of wages is an accident and not the result of a fixed law of exchanges, as has been pointed out.

The fluctuations of the labor rate are undoubtedly affected, if not produced, by demand and supply; but to contend that the general rate of wages in any country is thus produced, or governed, shows scant acquaintance with the subject. There is nothing to hinder skilled labor from flowing to any point where it is scarce, and, therefore, better paid. There is no duty or legal restriction on labor. It enters free into nearly all countries. In one week it can be transferred from New York to San Francisco, and in eight days from Manchester to Philadelphia.

Wages may rise for a time when there is a sudden demand for some product and a want of labor at some particular place; but this lasts only until workmen can move to that place and wages soon settle down to the normal rate.

No one would think of investing in a manufacturing or other business if he believed the important component of labor was to be the result of accident, or of demand and supply, which is the same thing; but this is not the principal evil produced by such a doctrine. It is one of the main causes, perhaps the principal cause, of strikes and many other circumstances that attend on skilled industry. Under such an assumption workmen naturally conclude there is no limit to wages and the more they can exact the better.

Mr. Jay Gould, during the great strike on the Missouri Pacific Railway System, in 1887, said: "Labor is like any other commodity. Its value depends on demand and supply." If this is true, why should not his workmen cut off the supply and increase the rate? Like Shylock, the workmen on the Missouri Pacific lines were only "practicing the iniquity which their employer taught."

Jay Gould was a worthy representative of the school to which he belonged—one that incites men to commit blunders and crimes by taunting them with their dependent position, and telling them their earnings and the conditions of their employment are an acci-

*Sometimes employed to mean free of local taxes or dues.

dent and not amenable to economic laws, which both employer and employed must alike respect; also, that labor and capital, instead of being joint agencies mutually dependent on each other, are antagonistic elements or components in useful industry. The theme, forming the subject matter of the present paper thus far is, I am afraid, presented in a form so compendious as to spoil its value. Still all the various points bear upon the compensation of skilled labor and should not be omitted.

I will now revert to the circumstances of employment, or the conditions under which personal service is rendered, and in doing so I will take the privilege of using a few extracts from a lecture delivered before the engineering classes at the Stanford University, in 1898, on "Works Administration."

First. In the scale of personal service is slavery, where workmen are not responsible.

Second. Time service, in which workmen are partially responsible.

Third. Piece work, where a workman is responsible for his own work alone.

Fourth. Contract work, where a whole working force is collectively responsible.

Now these four methods or systems of service have the several degrees of responsibility named; that is, from all to nothing. Responsibility is the key to efficient skilled service. It forms the distinction between free and slave labor and the incentive of effort. This proposition may seem strange, but it is certainly true. Whether it be a cause or a sequence, or both, we need not stop to inquire, so long as we find it a constant characteristic of contented and efficient effort on the part of those employed.

In respect to slavery, that no longer exists in any country where skilled industry is extensively carried on, and we need to refer to it only in illustration. A slave is not responsible for the product of his labor. That may vary more or less in proportion to what a master gives in return; but personally a slave is not responsible, because he is not a free agent. Emulation, respect and a sense of duty may in a limited degree enter into his incentives; but the subordination of his will and the fear of punishment are the main causes that enforce his service.

Time work, wherein the workman is paid for a term of service, is yet the most common form of employment. It stands next to slavery—not very near to it, perhaps, but next in the scale toward responsibility—and is practicable only because of the sense of per-

sonal honor and of justice due to the degree of self-respect existing among skilled workmen.

Under this system workmen are responsible so far as their sense of manhood and emulative pride produce responsibility, but no farther. A man is hired by the hour, day, week or month; but the terms are indeterminate. His wages are merely a rate. If he spoils his work or fails to render such service as common custom demands, he can be discharged and nothing more. The conditions of his engagement do not make him responsible. If he spoils work or fails by incompetence to earn his wages and a profit for his employer, it makes no difference; the law will give him his wages irrespective of everything but willful negligence and the malicious destruction of his employer's property.

The results attained by a time system in this country are certainly a compliment to the integrity and good faith of the skilled workmen of our time. Contrast it, for example, with the usages of common trading. If exchanges were to the same extent based solely on good faith and manly honor, would a like result follow? I am not claiming that faithful service is always rendered from honorable and unselfish motives. The penalty of discharge is always present, and the sentiments engendered by unions or trade organizations are often independent of an employer's interests, so that we can only wonder that the circumstances are not worse, when the time rate manner of compensating skilled service is considered.

The extent to which time work is used in skilled industries may be cited as an argument for its necessity; but it is not universal, and is constantly becoming less. Greater progress would long ago have been made toward a better system had it not been for efforts that have been made toward paternal systems, such as "profit sharing." These efforts, made, in most cases, by earnest and philanthropic men, have nevertheless failed to meet the real causes that lie at the bottom of labor dissension.

Such a statement as this needs some defense, but one may ask, What have workmen to do with profits not earned directly by their efforts and skill? Only a part of the profits in an establishment are thus earned. The profits depend on many things beside faithful and efficient labor, and, if profits not earned by labor are divided with workmen, it is a gift or bribe that destroys their independence and responsibility. The better class of skilled workmen of our day do not want such favors. This sort of patronage, especially when it takes the form of free gifts, is especially provocative of discontent and dissension indicating, as it does, class distinction and an unfair distribution of profits. What workmen want and need is

justice, fair dealing and responsibility for what they themselves perform and produce, and above all to learn what part this is. They have no right to more. They have as much reason to risk their labor as an employer has to risk his capital, service, management and implements, and what is wanted is to segregate the labor component and let it rest upon its own responsibility, do away with premiums, and, so far as possible, with a time system of service. It is degrading in the skilled industries of our time, and, while it cannot be at once removed, a beginning can be made, and above all we can study its nature and effects in the labor problems now convulsing the industrial interests of the country.

To illustrate this matter I will mention that, when in Switzerland last year, I visited the works of Messrs. Sulzer Brothers, at Winterthur, where 3500 men are employed in machine making. There was a large building, called a Casino, containing a library, dining hall, bath rooms for hot, cold and Russian baths, a fully equipped surgery, etc. The cost of this building could not have been less than $100,000, and I said to Mr. Henry Sulzer, senior member of the firm, "This Casino is a great concession to your workmen, for which they are no doubt very grateful." His answer was, "We did not give the Casino to the men. It is an essential part of the works, built out of earnings, and belongs to the workmen as much as to the firm. They manage it. It is a community property." "But," said I, "the profits to build the Casino were deducted from those of the firm." "Not at all," said he, "we had our share."

The piece-work system, by which is meant personal contracts with particular workmen—a mixed system, in which a part of the working force is made responsible and the rest are employed on the time method, is a bad system in many ways, for many reasons. In the first place, it is discriminating and unequal; and secondly, there is no impartial standard from which prices can be determined. The price is a matter of chance, depending on the choice or conscience of the employer. It is a "provincial idea," so to speak, and is a crude effort toward a contract system. It increases the responsibility of workmen without adding much to their independence. It does not succeed unless very carefully adjusted.

We are well aware of the extent to which it has been carried out in various shops, especially in New England; but if one will look into the matter carefully, it will be found that, wherever successful, there have been a very high class of workmen and some features of a contract system involved that modified discrimination among the men, and that rates were not fixed by accident or inde-

pendently in each shop, but by rules that have been generally established by custom in a district. Individual piece work is an undemocratic idea, not consistent with the spirit of our times, and will, no doubt, pass away for something better in the future.

The next system of service, if that term applies, is what has been called the contract system, or, as we may call it, the responsible system, in which labor is set off as an independent element in production. The consideration of this will consume some time, but it is well worthy of it, because there is no one here who can go out into the activities of the industrial world without having to face and deal with the labor problem.

To make clear what is meant by a contract system of labor, the best way will be to illustrate by an assumed example; and, as one class of manufactures is as good as another, a joiner works will answer the purpose.

In a factory of this kind are prepared all kinds of timber, house-furnishing material, sucn as flooring, ceiling, doors, sash frames, moldings and so on. All these things have regular prices, because made very uniform for average houses, and there are price lists published that apply over wide districts. For some things, like doors, sash moldings and flooring, the lists apply to the whole country within reasonable distances of transportation. The work, when not included in the price lists, is made to estimates in which the labor is always made up as a separate item, and the labor in listed articles is either known or ascertainable in all establishments; is better known, indeed, than other elements, such as material and expense, that must be included in estimates.

Suppose, then, that a joiner works is to be established, and that the owners, instead of hiring men by time to do the work, establish a contract system for the labor. The men are employed as in any other case, and are permitted to draw, in proportion to their rank and skill, a certain amount of money each week in proportion to the usual wages paid in such establishments; but the work, as a whole, is all contracted to the men, or to the shop, as we would say, and whatever money is advanced for wages is deducted *pro rata* from the labor estimates due at the end of the week or month for work turned out. The men being apprised of, or already knowing, the rate for making standard work, no difficulty would arise from this, and all irregular or special work would have to be estimated and include the element of labor. That amount could be posted in the works, or entered in a book kept by the foreman and accessible to the workmen. Each man would, as is the present custom, enter, each day, on his time card, the number of hours engaged on differ-

ent jobs, which would, as is also the custom in most places, have a catalogue or order number that would be entered on the tickets, with the time given to each number or order.

The whole shop would now be working on a contract system; every man, boy and apprentice included, and at the end of a month, week or any other time convenient, the completed work could be made up and compared with the amount paid out in advances to the men. If there is a balance due them, it is divided *pro rata* among all, in proportion to their pay rate, as indicated by the weekly or daily wages on which the advances are made. If there is a deficit, the men must make it good by a corresponding reduction.

All losses, by accident, carelessness or inefficiency of the men, should be made good to the firm or company, and all losses chargeable to the owners by detention, want of material or implements, or accidents due the plant, would have to be made good to the men. If a man seeking work represents himself falsely as to his skill or rank, the owners need not concern themselves about that. The men in the works will attend to that matter; because if rated above his capacity he would be imposing on all the rest and lowering their wages.

The establishment would be co-operative, divided into two departments or interests closely allied and interdependent. The workmen would have nothing to do with material, expense, profits, risks or capital, except in sustaining these as a foundation for their own part. The labor and their compensation would depend on their own efforts and skill. No foreman to watch the men would be required. They would do the watching themselves, and do it in an effective manner. Drones would be weeded out, or, what is more likely, they would be reformed, or not exist at all under such a system. The working force would be independent, interested and responsible. If a man needed assistance or favor, the whole force could extend it by giving him easy work, or in other ways. It is an ideal system, but is not an idea. On the contrary, it is a demonstrated fact.

The main ground of objection to a contract system of labor is the matter of estimates; but does any one undertake work without an estimate? and do not such estimates include a labor component? There may be a few exceptions, but not many.

This objection arises mainly from a desire to conceal the components of an estimate, and out of a system that has no fixed rate of profits. If employers have a rule of "get all you can," they should not complain if their workmen adopt a like rule. And if employers cannot provide and maintain a reasonable expense account, to be charged to product, and can not estimate the compo-

nents, including labor, they must not expect co-operative effort in their works. There are difficulties to overcome, all must admit, but how many we do not know until efforts are made to establish a contract system.

In the Manchester district, and I believe over England generally, this system prevails in the machine works of the country, and the accounts for wages are nearlv double as much as on the continent of Europe. In the Cornwall Iron Works, at Birmingham, there are about 6000 workmen, and, from information given me by one of the owners and the manager some years ago, I doubt whether, among all this number, there is anv mechanic paid on the time system. I once brought out from England example accounts to show how the divisions are made in the Geesley Iron Works, at Manchester, and published the matter here.

Some such system is used in the Baldwin Locomotive Works, Philadelphia, where, for 25 years, and after a great strike at that time, not a word has been heard of labor dissension. The same result will, no doubt, occur in any works where the skilled work is made free and responsible.

No one, I am sure, who has known me, will charge that I am wanting in sympathy for skilled workmen; but, if I am correctly informed, the policy of the skilled labor organizations in this country is at this time directly arrayed against the individuality and responsibility of their members, demanding that they do only time work, determine the working hours, limit the amount performed, avoid responsibility, destroy all distinctions of skill and become a homogeneous class like common unskilled laborers. I confess an ignorance of any logical reason for such a policy. One can understand how routine and unskilled labor might resort to a policy that must, to some extent, eliminate individuality, responsibility and manhood, in order to defend itself against the aggressions of organized employers; but skilled labor of our time is another matter and requires a different system.

I fear that, by adopting the tactics of unskilled labor, the mechanics of our time have missed an opportunity of becoming a co-operating factor in our skilled industries, assuming the responsibility of their part of the work and basing the wages demanded upon the product of the wages, looking at the "rate" instead of the "amount," and, as remarked, have lowered their calling to the rank of common labor, thereby provoking an opposition that is as serious as it is extensive.

In demanding a time rate for wages, irrespective of skill, and limiting the work produced, skilled workmen have assumed the Jay

Gould theory of wages, adopting the "demand and supply" theory, which leads to cutting off the supply to raise the rate.

The employers are obliged to act on the same theory, while most of them well know that the labor component in their cost account could be reduced, and the rate of wages raised 25 per cent. by a contract system in which the workmen would be free, responsible and co-operative in their efforts. I am not arguing in favor of the employers' position; I am only showing that they accept the workmen's demand and supply theory at its own valuation.

It may seem a selfish proposition to set off skilled labor as a peculiar calling. It must become so or disappear. The intellectual standard required is all the time increasing. Implements supplant empirical skill. The colleges are each year furnishing a greater share of the apprentices. In some recent visits to works in the Eastern States I was amazed to find how many of the apprentices had come from the colleges, and how rapidly such young men advanced. The natural sciences are taking the chief place in our institutions of learning, and if the skilled workman cannot conquer a place above the rank of common labor, it will be his mistake and misfortune.

The skilled labor component in industrial production presents at this time a greater problem than ever before. It is surrounded by new circumstances, by vast combinations of capital and interests that naturally tend to separate employers from workmen and to promote what the "unions" seem to be aiming at—the elimination of the individual and substituting a catalogue number in his place.

The aims being the same on both sides, the issue is thus narrowed down to how wages can be exacted or withheld. Animosities are growing stronger, and what the end will be no one can foresee. Secret profits, secret organizations, elimination of the personal element and of humanity, point to an increase of labor disturbance, which, as our European friends predict, will have its center in this country and its focal center on the Pacific Coast.

These pessimistic conjectures may have no immediate purpose; but we are compelled to consider the subject, and I think that any one, who has carefully observed the matter, must conclude that the first and only logical remedy is to make skilled labor responsible, so that its earnings shall arise directly out of its product by some method such as has been indicated.

Suppose, as another example of a contract system, the owner of a foundry were to assume an estimate for iron, fuel, sand expense, losses by accident, profits, and so on—data which his own books will furnish—and then contract with the workmen to produce

the castings by the ton, paying a weekly wage, charging it to the labor estimate and dividing the surplus, if any, *pro rata* among all the workmen,—not dividing it between the workmen and the firm, as the profit-sharers propose to do, but giving it to the men who earn it. Castings could be put into classes, according to weight, green or dry molds, and so on.

I can imagine no impediment to such an arrangement, except a want of confidence between employers and workmen; and, if confidence is wanting, we are in a bad condition indeed. I have acted as arbitrator in settling disputed points in such a system, and have found no trouble whatever. If tackle broke, or if losses occurred, by accident partly the fault of owners and partly of workmen, or if faulty castings were made, such things were adjusted without difficulty; and I must add that in no case were there any unreasonable demands on the part of the workmen, who became, in effect, co-partners in the business, and relieved the owners of many details of management and of expenses attending on time work.

The basis on which contract work must rest is an inflexible honesty in accounts and in all other matters; and, unless this component is present, there is distrust, and the co-operative idea cannot be put in practice. Under a contract system I have no doubt that the product of a certain amount of wages would, in most cases, be increased 25 to 50 per cent. over what time wages would produce, and there would be no grounds for strikes and contention, when custom had established prices, and this would soon follow.

Even our Asiatic friends are moving in this direction. The Chinese take contracts for building dykes in the Sacramento Valley at a certain price per cubic yard.

The title and scope of this paper do not include any remarks upon the *immediate* causes that have led to the late and present strike of skilled workmen in this city; but, as these causes are the results of conditions that have been discussed, some brief remarks will be in place here. Principal among these immediate causes is the fluctuation of prices in products and commodities, especially in the necessaries of life, such as fuel, food and clothing. During four years past these have appreciated in price from 30 to 40 per cent., according to different authorities. This is a tremendous change, even at the lowest figures. The increment in the price of commodities has been distributed among the components of production. One portion, I do not think more than 10 per cent. of it, has gone to wages, and the rest is distributed among the other three components—material, expense and profit. A good deal is consumed in rebates to foreign buyers of products. For example, steel rails are

now $28 per ton in this country and $20 per ton in England. Makers, in this country, sell steel rails in England, delivering them at a cost of $3 per ton for carriage and receive $17 per ton, or $11 per ton less than is charged in this country; and, as rails are not exported at a loss, there must be an excess of at least $8 per ton over a fair profit based on the cost of production. The tariff tax on steel rails is $7 per ton. Iron pipes, nails and many other commodities have nearly doubled in value during a few years past, and they so remain. This unsettlement of prices has a disquieting effect upon skilled men. They may not understand, for it is very hard to understand, how this disturbance of the components of production affects their wages. Other components sink in value under the great combinations of organized production. Then, why should not wages rise, or at least bear a constant proportion to the value of the product? This is the query that presents itself to a workman's mind; and, as he cannot, under a time pay system, determine even the place of his own work among the components, he is apt to overestimate this part.

We need a campaign of education, not only in determining the labor component in commodities, but also in the relation of wages to prices; and, above all, we need education in the policy and circumstances that can so suddenly affect the balance between the various components of cost. One would naturally expect a redundant literature on this subject from the unions; but, so far as I know, they do not discuss even the elementary laws that govern wages. The amount and rate are never separately considered, and, until this is done, no solution of the labor problem is possible on logical grounds, or need be looked for.

When skilled labor demands greater compensation, let such demand be put upon logical and equitable grounds, and it will find support in both public opinion and in legislation. A strike is war, and war is a relic of barbarism. The Swedes have a saying, "Killing people proves nothing." This might be translated into "Destroying wealth, time and business proves nothing."

If the labor component in production falls below its proper place, let skilled men show and prove this thing, and if strikes are then unavoidable workmen will have public sympathy. If a manufacturer sells his product abroad for a third less than he does at home, and taxes his workmen and his countrymen to make up the difference, let this be shown. If the expense account and profit are overestimated, and if the labor element is cut down accordingly, let this be shown; but force without reason is war, and war is barbarism.

The Boards of Conciliation and Arbitration in New Zealand offer at this time the most advanced solution of labor disturbance in so far as "treatment" is concerned. It dispenses with the barbarism of labor war, is logical and deserves attention in all countries. The limits of this paper do not permit its discussion here, further than a suggestion that it be examined carefully by every one interested in the subject.

# NOTES COLLECTED IN RELATION TO DOCKS AND HARBORS IN GREAT BRITAIN, FRANCE AND BELGIUM IN THE SUMMER OF 1900.

By Frank W. Hodgdon, Member Boston Society of Civil Engineers.

[Read before the Society, December 18, 1901.*]

The paper I have to present to-night is simply a summation of the information I collected in relation to harbors and docks on my trip to attend the Convention of the American Society of Civil Engineers in London, 1900, and I begin with the port where I landed.

## LIVERPOOL.

Up to 1890 the depth of water on the bar at the entrance of Liverpool harbor was only 11 feet at low-water spring tides, where to-day it is 27 feet for a width of 1500 feet. This bar is situated 6 miles from the shore line, at the entrance to a channel which the current of the river scours through large areas of sand banks. This channel is generally about 2000 feet wide and of ample depth. The sand banks on either side, for the greater part of the 6 miles, are exposed at low-water spring tides. The bar itself, between the 27 feet curves at low-water spring tides, is about 1 mile across. Before the dredging operations the large vessels could pass the bar only when the water was above half tide; the mean range of tide at Liverpool being 21 feet, while storm tides have been known to rise 9½ feet above mean high water.

In 1890, owing to the improvements made in other harbors, notably at Southampton, the Liverpool authorities decided to attempt the dredging of the bar, and equipped two of their large steam hopper barges with sand pumps for the work. These hopper barges had a capacity of 500 tons of sand, and the contract for the pumps specified that they should be able to fill the barges in one hour; but when they were placed upon the work it was found that they could load themselves in from 20 to 25 minutes. Finding that the work of these improvised dredges had improved the channel very materially, two larger dredges were built for this special work. The hoppers for holding the sand, instead of being fitted with the ordinary doors, similar to those in the scows used in this country, were fitted with a number of cylindrical holes in the bottom, closed by valves, and the load was discharged through these holes by having jets of water turned on it. These new dredges are each capable of carrying 3000 tons of sand, and when

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at work are filled in from 30 to 45 minutes. Up to the present time these dredges have removed from the bar at the mouth of the Mersey 45,000,000 tons of sand, and from the banks of the channel between the bar and Liverpool harbor about 5,750,000 tons. This sand has mostly been deposited about 2½ to 3 miles northwest of the bar channel. The channel, so dredged, has shown practically no tendency to fill again, and the efforts of the dredges are directed toward deepening and enlarging it.

The river in front of the city of Liverpool has a depth of 40 to 50 feet at low tide and the current is very swift, the bottom being largely sandstone rock. At the narrowest point it is about 3300 feet wide between the landing stages at Liverpool and Birkenhead,—practically the same width as our harbor between the Grand Junction docks at East Boston and the New England piers at South Boston.

At Liverpool the docks proper extend for a distance of 6 miles along the water front, and the Dock property has a width of 700 to 2300 feet. The Dock Estate owns the shore for a considerable distance beyond each end of the docks. There are no parks on the water front. The docks have a water area of 385 acres and 25 miles of quay frontage.

At Birkenhead, on the opposite side of the river, are large docks controlled by the same corporation, having a water area of 164 acres, with 9 miles of quay front. The largest dock entrances on the Liverpool side now have a width of 90 feet, and at ordinary tides a depth over the sill of from 28 to 30 feet. On the Birkenhead side the greatest width is 100 feet, and the depth of water 27 to 28 feet. In the docks on both sides of the river are situated eighteen graving or dry docks; the largest, the "Canada," having an entrance width of 94 feet, with a depth of water of 28 feet over the sill at mean high tide, and a length on the floor of 925½ feet.

Owing to the great range of tide, the sills at the entrances of the docks were until recently so high that at extreme low water they were exposed or only slightly covered, so that they could be easily examined and ordinary repairs made to them. With the great increase in the draft of vessels, it has become necessary to lower the sills of the docks, and those now being built are all provided with grooves for placing floating caissons which will exclude the water and enable the space inclosed by them to be pumped out and the gates examined without the necessity of building cofferdams.

These docks are the result of a growth of many years; but since 1885, at which time large extensions both at the north and

south ends of the docks had just been completed, very little was done on the docks other than ordinary repairs, until in 1891, finding that the size of vessels had increased very rapidly, the corporation sought authority to make extensive improvements,—practically to reconstruct a large section of the docks,—and in 1898 the plans were modified and extended so that the works now being carried out provide for the entire reconstruction of two sections of the docks, one about the middle of the northern half and the other near the middle of the southern half of the docks on the Liverpool side of the river.

Two new and large sets of entrances from the river are being built, each to consist of two main passageways and one small one in the form of a lock, for barges; each passageway is closed by two sets of gates, so that in case one is damaged the other will maintain the water in the docks. The two main passageways at each set of entrances are 100 feet and 80 feet wide, respectively, and the barge entrance 25 feet. The depth of water over the sills of the main passageways is 30 feet at the north end entrance and 27 feet at the south end at high-water neap tides. This will give a depth of 34 feet at mean high water. The interior docks are being reconstructed and deepened so as to accommodate the larger class of steamers. Large pumping plants are provided to artificially raise the surface of the water in the interior docks, so that they shall at all times have an effective depth equivalent to the depth over the entrance sills. The first dock into which the vessels pass, coming from the river, has a depth equal to the sill at the entrance, and this basin is used as a large lock, into which, at neap tides, vessels enter; and after the outer gates are closed the water is admitted from the interior docks, so that it practically becomes a large lock for vessels entering the interior docks.

On ordinary tides dock gates are opened about two hours before high water and closed at high water. During these two hours vessels can freely pass to and fro between the docks and the river. At the same time considerable quantities of silt are carried into the basin, and dredging is almost constantly going on to remove it. The cost of the improvements now in progress is estimated at £6,350,000, or about $31,750,000. During the year 1899 about $5,000,000 was spent on the work and in 1900 a slightly larger sum, and the works are still far from complete.

Formerly vessels received and discharged their passengers onto tenders, as the depth of water was not sufficient to enable the large steamers to go alongside the landing stage; but within the last few years extensive dredging has been done in the river in the

vicinity of the landing stage, and at the present time all passenger steamers, on arrival, go alongside the large landing stage (Fig. 1), which is a long floating platform, supported on iron tanks or floats, and there the passengers and baggage are landed. The vessel goes into the docks on the next high water to discharge and receive cargo. When loaded, they are brought out of the docks at high tide and anchored in the river, and about one hour before sailing time are brought alongside the landing stage to receive their passengers and baggage.

Fig. 1. Landing Stage and Ferryboat, Liverpool.

The docks at Liverpool are all founded on a soft sandstone rock, and in many cases the docks are excavated more than half their depth in this rock. The walls of all recent docks are built wholly of concrete, with a single course of granite as a coping stone (Figs. 2 and 3). The sandstone rock, while furnishing an excellent foundation, is very readily excavated without explosives, and the excavated material is mostly carried out to sea in steam hopper-bottom barges. The dock walls are now all built with vertical faces, as vessels are built with practically vertical sides.

In the work of reconstruction now going on it was deemed best to interfere as little as possible with the use of the dock, and in many cases where it was necessary to deepen the dock and

where the foundations of the existing walls were not far enough below the existing bottom to enable the deepening to be done safely, coffer-dams of timber were made and placed in front of the walls, and after these were pumped out excavations were carried down in sections under the walls and new foundations were put in, extending down below the line of proposed deepening. These coffer-dams were constructed of Southern pine timber 12 inches square, put together on the wharf in sections of 50 feet or more, then launched overboard and placed in position by the aid of hydraulic or steam cranes on the wharf. These sections were made water-tight by spiking a triangular strip of dry pine about 1 inch thick on two corners of every stick. When these timbers were placed side by side, hydraulic jacks were used to squeeze them together, and then they were bolted to stringers. This single thickness of 12-inch pine made a very tight dam against a head of from 20 to 30 feet of water. In placing them they were guided by a few piles of squared timber driven into the bottom. The lower edges of the sections were weighted with large stones lashed to them while the upper edges were lifted by the cranes. The spaces at the ends, between the timber sections and the wall, were made tight by a few piles driven close together, and then clay was deposited outside of and against the foot of the dam. Where small leaks were found, cinders were thrown into the water. These were sucked into the holes in the clay and the dam became water-tight.

Where the reconstruction was so extensive that the dock could not be kept in operation, it was cut off from connection with the other docks either by the existing gates or by special coffer-dams, and the whole area was pumped out and the work carried on in the open. The pumps used for keeping these areas free from water looked very crude, but I was assured by the engineers in charge that they were very effective and that repairs were easily made with but little delay. They were what I have always known as chain pumps, consisting of a cast-iron tube about 5 inches by 28 inches in section and in lengths of about 2 feet, bolted together to form a continuous tube from the point of discharge of the water down nearly to the bottom of the excavation. Through this passed two chains, to which was secured, about every 18 inches, a wooden board which practically filled the tube. The chains were operated by a toothed pulley on a shaft operated by a small engine. Usually two or more of these pumps were operated from the same shaft. They were run at a low speed, but maintained a constant flow of water.

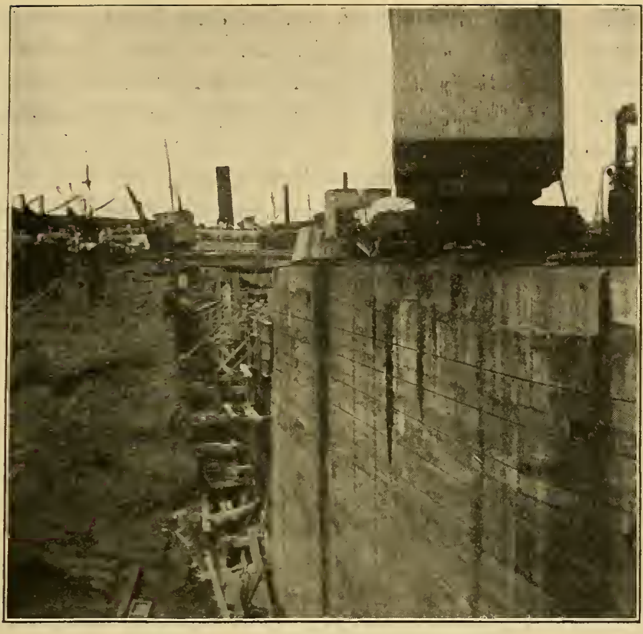

FIG. 2. NEW DOCK WALL, LIVERPOOL, SHOWING METHOD OF CONSTRUCTION.

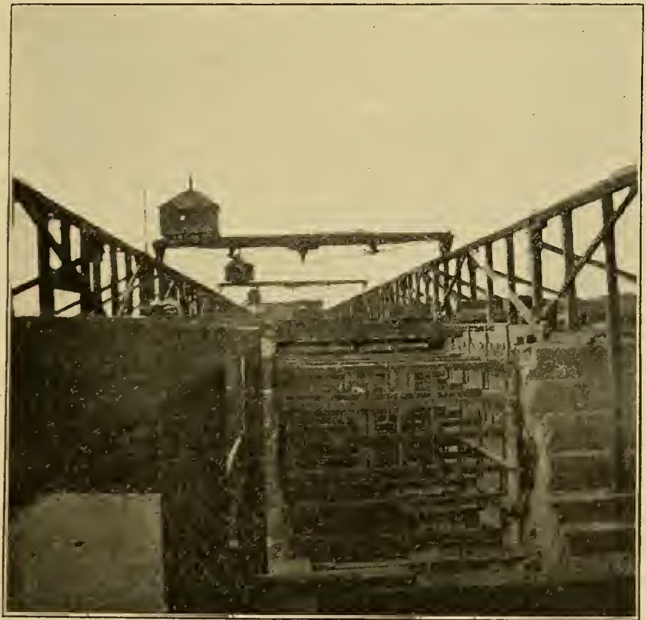

FIG. 3. BUILDING NEW DOCK WALL IN TRENCH ACROSS OLD GRAVING DOCKS, LIVERPOOL.

Owing to the difficulty of constructing coffer-dams around the river entrances to such a height that the whole work could be carried on continuously, the foundations for these entrances were constructed in coffer-dams extending only to about half tide, so that the works were flooded each tide. As soon as the tide fell below the top of the dam, pumps were set at work to free it and the work was carried on as expeditiously as possible until the rising tide overflowed the dam, when work was suspended until the dam could be again pumped out.

In all foreign ports and docks a feature which strikes one as entirely different from anything seen in America is the immense number of cranes of one kind or another situated along the quay. Nearly all the loading and discharging of vessels is done by these cranes, very little use being made, as a rule, of the winches and fixtures of the vessels themselves. These cranes take up considerable space along the quay front, and at Liverpool whenever new sheds are built two stories high the sheds are placed quite near the quay line and the cranes are placed on the roof (Fig. 4), the post of the crane being directly over the brick wall of the shed and the back leg running on a track on the ridge pole. Practically, all these cranes, as well as the motors for moving the dock gates and other machinery, are operated by hydraulic power. In construction work where we would use derricks steam cranes are generally used. In constructing the two walls, one on each side of a dock at Liverpool, two different styles of crane were used. The locomotive post and boom crane was used on one side, running on a track alongside the trench in which the wall was being constructed, and on the other side an overhead traveling crane, running on temporary trestles, erected on each side of the trench on which the wall was being constructed. (Figs. 2 and 3.) The principal work done by these cranes was raising the material excavated in the trench and handling the timber used for bracing the trench, the walls themselves being constructed of concrete, which was mixed at the surface of the ground and deposited in place through chutes. Formerly when the walls were built of stone, these overhead cranes were used for setting the stone.

## MANCHESTER SHIP CANAL AND DOCKS.

Leading from the river Mersey, just above Liverpool and on the opposite side of the river, is the Manchester Ship Canal, which extends up into the city of Manchester. This canal is $35\frac{1}{2}$ miles long, with a bottom width generally of 120 feet and with sloping banks, except that in places where it is excavated through the rock it has practically vertical sides. It has a navigable depth of

26 feet. The locks are 65 feet wide and 600 feet long. There are four sets in the canal in addition to the set where the canal opens into the river. The first section, between the entrance into the Mersey and the first set of interior locks, is 21 miles. The water level in this section is about the same as the ordinary high tide in the river. The locks have a lift varying from 13 to 16½ feet. The total difference in elevation between the surface of the water in the docks at Manchester and in the lower section is 60½ feet. During extreme tides the water is allowed to flow into the lower section (21 miles) of the canal; and, as originally planned, it flowed in and out through sluices located in the bank at various places along the section; but owing to the large amounts of silt

FIG. 4. CRANES ON ROOF OF SHED, LIVERPOOL DOCKS.

which were carried into the canal at such times and which had to be removed by dredging, and owing to the cross currents created, it was finally decided to close all the openings except the one at the entrance of the canal; and while the amount of tidewater which enters and leaves the canal now is somewhat less than formerly when all the entrances were in use, no injurious effects on the river below have been noted.

During extreme high tides the current created in the narrowest sections of the canal by this tidal flow reaches the velocity of about 5 miles per hour for short periods.

The banks of the canal, where the cutting is through earth, have been protected by stone paving; but even up to the present time in many places they show signs of cutting.

The docks at Manchester are on quite an extensive scale, and large tracts of additional land have been purchased with a view to extending them. The dock walls are all built of concrete, but from a short distance below the surface of the water to the coping stone they are faced with blue brick, the coping stone, as at Liverpool, being granite. (Fig. 5.)

Hydraulic power is used for operating the cranes along the docks and the gates of the locks.

One interesting feature of the work is the Barton Aqueduct, which carries the Bridgewater Canal across the ship canal. In order to allow the passage of vessels in the ship canal this has been constructed as a turn-table drawbridge, gates being constructed at each end of the canal box, both on the abutment and on the bridge, leaving a space of about 18 inches between the gates. When the bridge is swung off to allow the passage of vessels, it carries with it the canal box full of water, only the small volume lying in the space of 18 inches between the gates being lost. At times canal boats are caught on the bridge when the draw is to be opened, and they remain in the box while the bridge is being swung off. The drawbridge is a heavy steel-girder bridge, quite narrow, and is operated by hydraulic power from a pumping station near-by on the shore, which also furnishes power for operating a highway drawbridge immediately below the aqueduct bridge.

Vessels of over 8000 tons burden have navigated the canal, and very little delay is occasioned in passing through the locks. Facilities for docking and repairing vessels have not been provided here so extensively as in some other parts. The canal is connected with the barge canal system which covers the larger part of England and Wales, and a large part of the merchandise brought in vessels both to Liverpool, Manchester and other ports is discharged directly into the canal boats for distribution to the various inland centers, the railroads performing a very much less important part in the transportation of heavy goods than they do in this country.

## LONDON.

At London the dock system is entirely different from those heretofore mentioned. The rise and fall of the tide is very great, the mean rise and fall being 17½ feet at London bridge. At various points along the river piers are built out, at the ends of which the coastwise steamers lie to receive and discharge their cargoes.

These piers are too narrow to permit of mooring the whole length of the vessel directly to the ends of the piers, so mooring buoys are placed in the river above and below the piers, and to these buoys the mooring lines are made fast. All along the river below the Victoria embankment, and also on the Surrey side, the warehouses are built at the water's edge and steamers and barges are brought alongside and lie there on the bottom while their cargo is discharged into the warehouses by long-armed cranes which are attached to the faces of the buildings.

In some places the bed of the river is prepared and leveled above the level of low-water mark, so that the flat-bottom barges

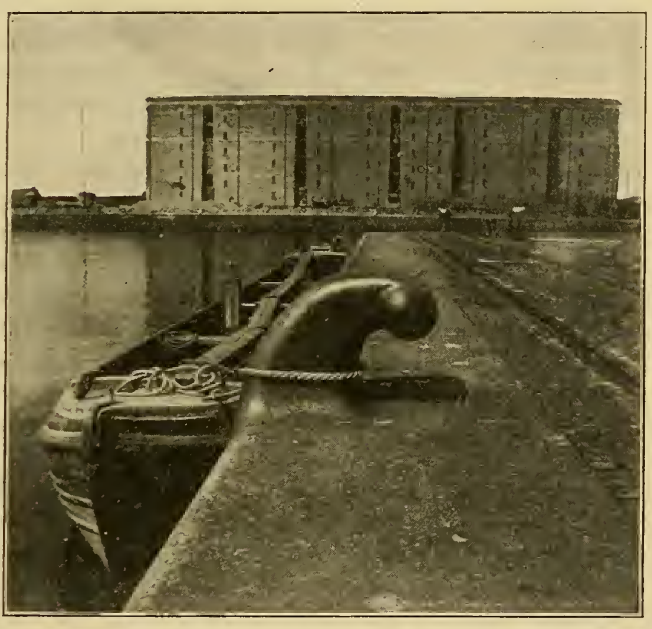

FIG. 5. BELAY POST AND CANAL BOAT, MANCHESTER DOCKS.

can lie there when the tide recedes without dropping too great a distance below the level of the wharf. At various points in the river are placed mooring buoys, to which steamers are made fast, stem and stern, to prevent their swinging while their cargo is discharged over the side into lighters, which are then floated up and down the river to the various warehouses. These lighters or scows are also taken into the various docks and loaded from steamers or vessels lying there, and then are taken out again into the river to the warehouses, railroad stations and canals.

Docks similar to those at Liverpool are built on both sides of the river at various places. Some of the oldest, as the London and

St. Catherine's docks, are just below the Tower and are very massive, having heavy stone and brick warehouses built right on the quay line. Below these, on the same side of the river, are the East and West India docks, which are located on the inside of a bend in the river and have openings into the river at both ends. Below these again are the Victoria and Albert docks, and at the mouth of the river are the new Tillbury docks, which are the only ones into which the largest steamers can enter, the tidal basin having a depth of 23½ feet at low-water spring tides and 42½ feet at high-water spring tides. The depth on the outer sill of the lock leading to the closed dock is 1½ feet less. The Victoria and Albert docks accommodate the larger part of the Peninsular and Oriental steamship lines, as well as many others. There are large cold storage warehouses for receiving and storing frozen meat, and there have just been installed at the Victoria dock small grain elevators for transferring grain from barges to cars.

Some of the dock walls in the Victoria dock are constructed of vertical cast-iron I-beams, with webs and flanges over 2 inches thick, the spaces between the I-beams being filled in with brick arches. There are also a few pile piers built of square timber.

The walls of the Albert dock are constructed wholly of concrete except at the entrances, where they are faced with brick. Very little is now being done in the London docks in the way of improvement, and I was told by the engineer at the Victoria and Albert docks that it was almost impossible to get the authority to make the really needed improvements.

At the West India docks one of the large entrance locks was being reconstructed, the arch of the invert being taken out and replaced with one having a greater radius in order to allow modern vessels with flat bottoms to enter, the depth of water at the sides being increased about 4 feet; at the same time the lock is being lengthened and an additional pair of gates placed at the inner end. In order to carry out this work a coffer-dam of timber was built on the apron outside the entrance gates, and at the inner end, in the dock itself, a circular coffer-dam was being constructed of Southern pine timber, each pile constructed of two sticks 12 inches square bolted together. The piles thus made, being driven close together in the dock, form a semicircular wall 2 feet thick around the inner end of the lock. These piles were driven as close together as possible in sections of ten piles each. When one section was driven a space of about 10 inches was left and then another section of ten piles was driven. This was continued until the whole distance had been covered. Then, by the aid of divers, the exact space between

each two sections was measured and a pile, cut slightly larger than the space to be filled, was driven into it, thereby wedging all the others together.

To strengthen the top of the coffer-dam, a horizontal timber arch 8 to 10 feet thick and 12 inches wide, made of planks 3 inches by 12 inches, was built against its inner face. Between this and the bottom it was proposed to put in additional bracing by the aid of divers. Just before my visit, the dam had been completed with the exception of some of the under-water bracing, and an attempt was made to pump it out. When the water had been lowered about 12 feet, the dam gave way near the middle, and at the time of my visit it was being reconstructed with the intention of putting in additional under-water bracing. In placing the new invert in the lock sections 5 to 6 feet wide are first cut out of the old invert and a new invert of concrete built in place; then the intermediate sections are cut out and sections are built in between the sections previously constructed. The entrance at which this work is being done is 55 feet wide.

On the opposite side of the river is another large system of docks used largely by sailing vessels.

There is a large passenger traffic on the river in small paddle-wheel steamers which run up and down the river from Westminster bridge and Greenwich every half hour and other steamers which run much oftener to intermediate points.

Along the banks of the Thames are many dry docks opening directly from the river. They are large enough to accommodate the ordinary sailing vessel, and some are of considerable size. The sills are above the plane of low water; and after vessels are placed in them and the gates are closed, the docks are emptied by allowing the water to flow out as the tide falls, the sluice being closed at low water, and after the vessels have been cleaned or repaired the water is allowed to enter at high tide and the vessels are floated out. This makes very cheap dockage, no pumping plant being required.

At Liverpool some of the older dry docks, opening from the wet docks, are equipped in a similar manner by having sluices built through the walls of the main dock out into the river; but all the larger and more recent docks are built with pumping plants, the Canada dock, the largest now in operation, being equipped with pumps which will empty the entire dock in 1½ hours. This method of operating dry docks, of course, can be used only where there is a considerable range of tide, as there is in Great Britain.

BRISTOL.

From London I went to Bristol and to South Wales. The Avon at Bristol is a small stream, but the tides are very great, and vessels of a size similar to our coastwise steamers come up into the city, where a section of the river has been impounded as a dock, the river in places between the city and its mouth being almost dry at low tide. The docks here are owned by the municipality and considerable work has been done in improving the channel of the river and in building retaining walls to prevent the banks from washing down into the channel. At Avon mouth a large dock has been constructed to accommodate foreign traffic.

The city investigated the best method of extending its dock facilities. One plan considered was to build a dam with sluices and gates at the mouth of the river Avon, and to turn the whole length of the river between the city and the sea (about 8 miles) into a dock. One serious objection to this plan is the large amount of silt which is carried by the river and which will settle in any such dock and require continual dredging in order to maintain the required depth of water.

The plan which has been adopted and authorized by Parliament in 1901 is for a new dock having an area of 30 acres in the lowland adjacent to the present dock near the mouth of the river. As the needs of the port demand, this can be extended and other docks located on the opposite bank of the river. Two hundred and thirty acres of land adjoining have been acquired for use in connection with the dock. On both sides of the river there are large areas of lowland at present unoccupied except for cultivation.

The dimensions of the docks are as follows:

| | Areas. | Length of Quay. | Depth of Water on Sill. Neap Tides. | Spring Tides. |
|---|---|---|---|---|
| At the City | 85 acres | 7500 yards | 23 | 33 |
| Avon Mouth | 16 " | 1200 " | 28 | 38 |
| Proposed New Dock | 30 " | 1110 " | outer 37 | 47 |
| | | | inner 26 | 36 |

At the new dock the length of the entrance lock is to be 850 feet and the width 85 feet. A graving dock is to be built of about the same size as the entrance lock. The depth of water in the entrance channel from the river to the dock is 8 feet at mean low water. Many improvements were under way at the time of my visit. A new grain elevator, just completed, is operated wholly by electricity, the grain belt conveyers and elevators being run by independent motors. The electricity used was generated in a power station within the dockyard, the generators being run by gas engines using gas made on the premises. The sheds on the docks

were being enlarged and extended principally by sheds constructed of I-beams set on end in masses of concrete in the ground, the roofs being made of corrugated galvanized iron bent in the form of an arch between I-beams connecting the heads of the posts. The construction was very light and stiff, but would hardly stand the heavy snows of our climate. As at most of the larger docks, there is a pumping plant here to artificially maintain the level of the water in the dock at 30 feet above the sill of the dock entrance. The tide is here so great that the outer gate sill is exposed at each low water, so that it can be readily examined.

At these ports the method of handling the grain is very different from our own. There the grain is sold in small lots, and when it is placed in the elevator each lot must be kept separate. For this reason the elevators are built with floors instead of bins, and the different lots are separated from each other by movable wooden partitions or fences. The system of grain inspection and grading, by which all grain received of the same grade is placed in one bin, no matter by whom owned, is not in use there.

### CARDIFF.

This is the largest coal-shipping port in Great Britain, but the trade in general merchandise is now increasing and additional facilities are being constructed to accommodate it. At the same time a new dock is being constructed, a large portion of the excavation being already done and a portion of the dock walls erected. The coal cars used are on four wheels and hold from 7 to 10 tons; all have swinging doors at the ends, and as they are shunted down to the side of the vessel they are picked up by machinery of various forms and the whole load is dumped directly into the vessel. In some cases the ordinary dock crane is used, the car being picked up by chains passed under the body and swung out over the bunker or hatchway of the vessel, and the car is tipped by means of a second chain on the crane and its contents discharged into the vessel. At other places hydraulic elevators (Fig. 6) stand on the edge of the quay; onto these the car is pushed, raised to the necessary height and tipped, and its contents are discharged through a chute into the vessel. Another and slower method, which has nevertheless been adopted in some cases in order to avoid breaking the coal, is as follows: A large iron tank, which looks like a coalhod, is lowered into a pocket in the quay, the car is run down onto a tipping platform in front of the coalhod and its contents are dumped into it. The hod is then raised by a crane, swung over and lowered into the hold of the vessel, and when it has reached the

bottom its contents are discharged by disconnecting the bottom from the sides of the hod and raising the sides. In this way the coal is deposited with the least fall and the lumps are not broken.

The present Bute docks at Cardiff have an area of $110\frac{3}{4}$ acres, and the new dock in process of construction has an area of 50 acres; total, $160\frac{3}{4}$ acres. The depth of water on the sill is 25 feet at high-water neap tides and 10 more on springs. There are nine graving docks besides pontoon and gridiron.

There are many excursion steamers at these ports. They are shallow-draft paddle steamers, long and narrow, and lie at piers outside of the docks, and at low tide rest wholly on a mud bottom which is bare at low water. The mean range of tide at these ports is 24 to 28 feet; spring tides 31 to 37 feet.

BARRY.

Barry is one of the boom towns of South Wales. The construction of the large docks here was commenced about fifteen years ago, and they have been open about eleven years. The population in this vicinity at the time of the beginning of the work was about 800, while at the present time it is 35,000. The principal business is the mining and shipping of coal. Large quantities of timber to be used as props in the coal mines are imported principally from Norway. The machinery for handling the coal is substantially the same as at Cardiff, but of a somewhat newer design. The area of the dock is 114 acres and the length of quay 19,540 feet; the entrances have a width of 80 feet. The depth over the sill is 29 feet at neap tides and 37 feet at spring tides.

There are two sets of dry docks; one set is 867 feet long and the other 778 feet long, both having a width of 100 feet on the floor. At the time of my visit one set was occupied by three vessels; at one end there were two vessels abreast of each other and at the other end one vessel standing on its keel and leaning against the side of the lock, there being space enough alongside of her for another vessel. Both sets of docks can be divided by gates near the middle into two separate docks.

SOUTHAMPTON.

The next port I visited was Southampton. The docks here, with the exception of the town quay and Royal pier, which are used for excursion steamers and local vessels, are owned by the London and Southwestern Railway. There are three main docks, having an area of $44\frac{1}{2}$ acres. Of these only one, having an area of 10 acres, is a closed dock. In the large Empress dock and along-

side the quay fronting on the river Itchen there is a depth of not less than 28 feet at low water. The mean range of tide is about 10 feet. There are five graving or dry docks and a sixth is in course of construction. The largest dock has a length of 750 feet, with a depth on the sill of 29 feet at high-water neap tides and $32\frac{1}{2}$ feet at spring tides.

At these docks a cold storage warehouse was in course of construction on filled land alongside the quay front. The foundations consist of concrete piles 14 inches square and 40 feet long. They were driven by a steam hammer their whole length into the filling, which appeared to be composed principally of silt. These

FIG. 6. HYDRAULIC CRANES AT CARDIFF.

piles were built in a vertical position and had four $1\frac{1}{4}$-inch iron rods inclosed in the concrete throughout their length. At the point of the pile the rods were bent and entered the back of a small cast-iron point. About every 18 inches the rods were tied together with plain iron wire about the size of our large telegraph wire. The concrete was quite rich,—about one part Portland cement to two parts of river gravel,—which was dredged from the river within half a mile of the quay. While being driven, a cap of cast iron was placed on the head of the pile; and this cap had, on its upper side, a socket, in which was placed a depth of about 6 inches

of sawdust. On this was placed a wooden block, and the steam hammer struck on the top of this block. This was used to cushion the blow and prevent shattering the head of the pile. The man in charge of the work told me that they had no difficulty in driving the piles to the required depth.

On the foundation thus formed was being constructed a building consisting wholly of concrete strengthened by plain iron rods. The posts were built like the piles, those in the basement story having five rods embodied in the concrete, and the posts were generally about 10 or 12 inches square. The beams from post to post had a number of round rods, generally $1\frac{1}{4}$ inches in diameter, sagged between the posts and extending over the head of the post and a few inches beyond, where the ends were bent at right angles. By these beams the floor was cut up into panels of about 4 x 6 feet, and across these was constructed, in a similar manner, a floor of concrete about 6 inches thick. The walls were carried up as plain slabs between the posts, with smaller rods, generally square, spaced about every 8 inches. This form of construction was quite new, and I heard of it from a number of different engineers. Shortly before my visit there had been an accident and the frame and trestle which supported the piles during their construction had fallen. In constructing the piles the molds or forms were left on for about two days after the concrete had been placed; then they were removed and the piles were allowed to remain in the same place for about twenty days. At the end of that time they were taken down and stored away and not driven until after they were at least two months old. When the trestle work holding these piles fell a large number of piles fell with it. At the time of my visit the wreckage had been cleared away and the trestle was in process of reconstruction. A number of damaged piles were scattered about the yard, and I was surprised to see a considerable number which had simply been bent in the form of a bow, the middle ordinate of the curve being from 1 to 2 feet, while the concrete hardly showed a crack. They were trying the experiment of saving what they could of these damaged piles by cutting away the concrete from the bent portions, then cutting out the bent iron and attempting to reunite the straight portions by placing them in line, putting in new lengths of iron to take the place of that which had been cut out and adding new concrete while the pile remained in a horizontal position. The old and new iron rods were held in place by slipping short sections of pipe over the joints.

At Southampton can be seen long sections of the old masonry wall which formerly surrounded the city, and one of the old city

gates still obstructs one of the main thoroughfares. This gate, known as the Bar gate, has become such an obstruction that its removal is being agitated.

HAVRE.

There is a daily service of steamers from Southampton to Havre, which is the largest of the French ports. It has a basin or outer tidal harbor where small vessels lie, but they cannot come alongside the quay walls at low water. The docks proper consist of eight basins. The entrance to the largest of these is 100 feet wide, with a depth on the sill of 29½ feet at high-water neap tides and 35 feet at spring tides. At the present time the docks can be entered only at high tide, and the outer harbor is too small for the needs of the port; but work is now under way for constructing a new entrance to the main dock by which vessels can enter through a lock at any stage of the tide.

At the same time stone jetties or breakwaters are being constructed, extending from the shore on both sides of the entrance of the present harbor, inclosing an area nearly 1000 meters square, to be dredged out as a new outer harbor.

As in the English docks, cranes are to be found scattered all along the quay line. Those at the coal dock are operated by electricity, while the others are mostly hydraulic.

There are six dry docks, the largest being 492 feet long over all. This dock has been found to be too small, and it is now being lengthened so as to enable it to dock vessels 200 meters long. The foundations here are very poor and the extension of the dock is being constructed on a large compressed air caisson. The entire end of the present dock was first removed and the excavation of the site of the extension was made in the open air as far as was possible; then the steel caisson was built in the excavation and sunk into place, the extension being built upon it as the work proceeded. At the new entrance the lock is being built in the same way, the work being divided into a number of sections and each being built on its own caisson. The breakwater inclosing the new outer harbor is being built up to the level of low water, of rough quarry stone, faced on the sea side by large blocks of artificial stone. The portion above low water is a heavy masonry wall laid in cement. The ends of the breakwater adjoining the entrance channel will be built of masonry with vertical sides founded on a compressed air caisson carried down to a depth sufficient to allow future deepening of the entrance to 8½ meters below low water.

ANTWERP.

Antwerp is situated on the river Scheldt about 60 miles from its mouth. A quay is built along the whole city front, a distance of about 2 miles, and a width of a little over 300 feet is used as a wharf, having railway tracks its whole length. Back of this wharf is a paved street.

In addition to this river front there are three sets of docks, having a total water area of about 166 acres, with about 7 miles of quay. All the deep-draft vessels discharge and load in the river, where there is a depth of not less than 28 feet at low tide. There are six dry docks opening from the wet docks, and in addition there are four private dry docks and a gridiron opening from the river. There is the usual equipment of hydraulic cranes, and adjoining one of the docks in the lower portion of the city is a large brick grain elevator equipped with fan conveyers. The grain discharged from vessels is poured into manholes in the quay, which connect through pipes laid just below the surface with exhaust fans in the elevator which suck the grain to the elevator. There is no equipment for taking grain in bulk from the vessels. It all has to be placed in sacks and hoisted out either by cranes or by the ship's own winches and poured from the sacks into the manholes in the wharf.

The river is very crooked and flows through an alluvial soil; the larger portion of the banks is protected by brush fascines, and much dredging has been done to improve the channel. The average rise and fall of the tide is about 11½ feet and on spring tides nearly 15 feet.

One feature was different from anything I saw in any other port. At the foot of the main street leading up into the city was an old castle right on the quay, and extending from this for a quarter of a mile down river an elevated platform 50 feet or more wide has been built level with the tops of the wharf sheds, its front line being 20 or 30 feet back from the quay where the large steamers discharge (Fig. 7). This forms a promenade or recreation ground for the people in that section of the city, where they come and enjoy the breezes blowing across the river. At the opposite end from the old castle, which is now used as a museum, was a restaurant or café. Near the museum was a large floating landing stage, where the excursion steamers and ferries plying across the river made their landing.

BOSTON.

Boston is situated on the east coast of England about 6 miles from the mouth of the river Witham, in Lincolnshire. The

river has been straightened at various times under authority of acts of Parliament, so that at the present time it follows but a small portion of its original channel. Its depth varies from 21 feet at its mouth to 18 feet at high-water neap tide at the dock. The mean range of tide is 16½ feet.

The dock was constructed under an act of Parliament passed in 1881 and has a water area of about 7 acres and about ½ mile of quay front. The entrance lock is 300 feet long and 50 feet wide, with a depth of water on the sill of 18 feet at high-water neap tide and 25 feet at spring tide.

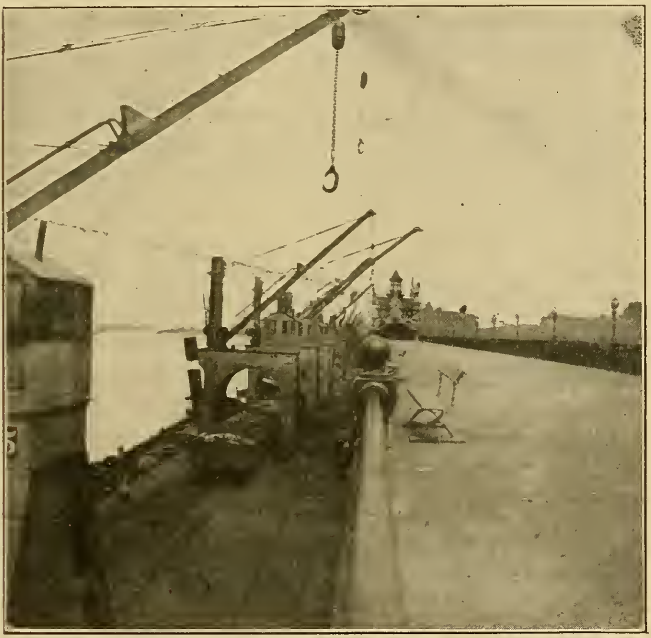

FIG. 7. RIVER BANK AT ANTWERP, SHOWING CRANES AND FREIGHT BELOW, AND PLEASURE PROMENADE ABOVE.

The principal business is fishing, thirty-seven steam trawlers sailing from the port. It has also a considerable business in shipping coal. The dock is equipped with hydraulic cranes and grain elevators, being quite a modern plant on a small scale. It has a marine railway for repairing fishing vessels and an artificial ice plant for supplying the fishermen with ice. Large quantities of ice are also imported from Norway. The municipality also owns a railway connecting the dock with the Great Northern Railway.

Boston is situated in the fen district and most of the country back of it is protected from the sea by dikes, the drainage being

through the rivers, in which are constructed large sluices for controlling the drainage and keeping out the tides. One of the largest of these sluices is in the Witham just above the center of the city and another is in the branch of the Witham just below the dock.

The principal sight in the old town is the St. Botolph church, which stands on the bank of the river just below the main sluice, and its tower is known as "Boston Stump." The floor of the church is so low that in storms the tide has covered it to a depth of several feet.

Wednesday is market day in Boston, and on that day the Square is filled with booths and farmers' wagons. During the rest of the week the Square is practically deserted.

### HULL.

Hull is situated on the north bank of the Humber, about 20 miles from its mouth. There are two sets of docks, one owned by the Northwestern Railway Company and the other by the Hull and Barnsley Railway.

The first set has an area of about 140 acres. The largest entrance is through a lock 320 feet long with a width of 80 feet. The depth over the sill is 22 feet at high-water neap tide and 28 feet at spring tide. There is one graving dock 501 feet long with an entrance 50 feet wide, having a depth of water 21 feet on the sill at spring tides and 15 feet at neap tides. The mean range of tide is about 16 feet. The river Hull, a small stream which flows through the center of the city, is used by small vessels.

The large Alexandra dock of the Hull and Barnsley Railway has an area of 46 acres, the entrance lock being 550 feet long and 85 feet wide, with 34 feet of water on the sill at spring tides and 28 feet at neap tides.

All these docks are equipped with hydraulic cranes and machinery for loading coal, and at the Hull and Barnsley Railway large quantities of timber are imported. The present dock accommodations are inadequate and surveys and borings are now under way for a large dock below the present Hull and Barnsley Railway dock.

The river Humber is quite wide opposite the docks and there are many shoals and middle grounds. Large quantities of silt are carried to and fro by the tides and considerable difficulty is found in keeping the entrances to the docks clear. Dredging is constantly going on and sluicing arrangements are used for scouring the silt away from the gates.

GLASGOW.

Glasgow is situated on the Clyde about 21 miles above Greenock. The mean range of tide is about 9½ feet. Formerly the bed of the river was above mean sea level at Glasgow, but by dredging and other improvements there is now a depth of 26 feet of water at high-water spring tide and 24 feet at neap tide. Below the bridges the river front is walled up and used as a quay and in the city are also three docks having an area of about 75 acres with about 4½ miles of quay front. These docks are open to the river and the tide rises and falls in them. The trade of the port has grown so large that two new docks are in process of construction about halfway down the river and a third is in contemplation.

There are a number of graving docks and marine railways. The shipbuilding yards are located along the river front below the city. The foundations for structures are poor and considerable difficulty has been found in constructing and maintaining the quay walls along the river bank. At one point they were reconstructing a section at the time of my visit and the engineer informed me that this was the fourth wall which had been built in that place, the previous ones having all failed owing to the poor foundations. The wall under construction is being built on a steel caisson which was sunk by the pneumatic process, and the wall of brick and concrete was being built as the caisson sank into place. Two sections adjoining each other were being built at the same time.

In the river below the bridges are many ferries. Two of these are for teams as well as for foot passengers. One is a large iron framework carrying a platform which can be raised and lowered by means of large screws, the whole being mounted on a steel hull which looks like a flat scow and in which are the engines for operating the propellers and the screws. This ferryboat plies across a narrow portion of the river and is made fast bow on to the quay wall on each side. The movable platform is kept on a level with the wharf and connection is made between the platform and the wharf by a short flap. The boat is double-ended, like our own ferryboats, so that it does not have to be turned around. The fares are all collected at one end, there being different passageways for the passengers going aboard and for those leaving the boat.

The other steam ferry lands on a paved beach on either side of the river and is like our own river ferryboats except that it is operated by steam. Two chains are stretched across the river and pass through slots in the boat and pass around drums which are operated by an engine. The landing is made by lowering a drop onto the beach at either end.

The water in the river is very foul and much complaint is made on account of its offensive character. Practically all of the sewage of the city empties into the river.

The cranes along the quays are mainly operated by hydraulic power, but the question of changing the equipment to electricity is now under consideration, and at the time of my visit a committee was visiting Hamburg to investigate its use at that port. In the newest dock there is a depth of water of not less than 22 feet at low tide.

The land rises rapidly from the river bank, so that the main portion of the city is quite high. The railway from Edinburgh enters the city through a tunnel on a steep grade. On the arrival of the trains at the entrance of the tunnel at the top of the grade the locomotive is detached and one or more brake vans are attached in its place; then the locomotive proceeds to the rear of the train and starts it down the incline. The train is then controlled by the brake vans until it enters the station. On leaving the station the process is reversed, the brake vans remain attached to what is then the rear end of the train and the locomotive is attached as usual. On the outgoing track is placed an endless cable operated by a steam engine at the head of the grade. Each brake van is equipped with a clutch which takes hold of the cable, and this assists the locomotive in overcoming the grade. At the same station another line of railway comes in at right angles to the first through a tunnel at a lower grade, making a station of two stories.

In nearly all the ports visited the docks are connected more or less directly with the barge canal system. Many of these canals were built at an early date and are not large, but reach into the rural districts.

At Trevor, in Wales, I saw a fine piece of engineering work in connection with the Shropshire Union Canal. The Pontcysylltau Aqueduct (Fig. 8) was built by Mr. Thomas Telford to carry the canal across the valley of the river Dee. It was begun in 1795 and completed in about ten years. It consists of nineteen arched spans of 45 feet each. In the center it is 130 feet high and its total length is 1007 feet. The ironwork is all cast iron except the bolts. Each span consists of four arched ribs, each rib being cast in three pieces bolted together. On top of these ribs is placed a cast-iron box 12 feet wide with a towing path 4 feet wide along one side. The cast iron box extends 11 feet into the embankment at each end. This canal is still in active use, the boats navigating it (Fig. 5) being about 5 feet wide, 4 feet deep and 40 to 50 feet long. The

ironwork of the bridge appeared to be in very good condition, though some of the arched ribs have been broken and repaired by

FIG. 8. NORTHERN SPAN PONTCYSYLLTAU AQUEDUCT.

clamps bolted to them. The towpath of the canal makes a very pleasant walk, and, judging from its appearance, is much used for this purpose.

## SEPARATION OF OIL FROM CONDENSED STEAM.

J. R. Bibbins, Member Detroit Engineering Society.

[Read before the Society, January 24, 1902.*]

The object of the experimental work detailed in the following pages was to evolve some method of freeing engine condensation of entrained oil occurring either in free form or entirely in the form of emulsion. The objective point of application of this prospective method of oil separation was the condensing plant of Station "C," of Detroit, Edison Company, which is at present operated in connection with two 400 horse-power McIntosh & Seymour tandem compound engines during periods of alternate heavy and light load. The relative positions of engines, condensers and exhaust piping are shown in Fig. 6. The condenser is a 1600-square-foot Worthington surface condenser, and discharges its condensation in either or both of two ways, namely: First, by means of a small automatically controlled pump into a coke filter constructed specially for the purpose of removing the oil, and thence directly into the boiler feed. The filter in shown, in vertical section, in Fig. 1. Second, by means of a siphon leg overflow directly into the sewer. The outlet from the filter shown in Fig. 1 taps into a 4-inch feed pipe leading from the discharge of the condenser circulating pump, from which the boiler feed is drawn at 150 degrees Fahr. average. The plant does not use city water directly for circulation and consequently for cooling purposes, but employs a cooling tower which receives and cools the hot discharge from the circulating pump. The before-mentioned tap from pump discharge is then a tap from the hot circulation water entering the tower to be cooled; this water then being more suitable for boiler feed than cold water from city mains.

### OCCURRENCE OF OIL.

No trouble was experienced in the operation of the plant as long as the condensation was allowed to overflow into the sewer and the boiler feed was taken directly from the hot pump discharge from the condenser. After the instalment of the special coke filter the condensation was then pumped through the filter and thence into the boiler, thus completing the water cycle (boiler-engine-condenser-filter-boiler) without serious waste. This operation continued for some months, during which time the coke was renewed at intervals of three or four weeks until it was found that con-

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siderable oil had collected in the boilers, presumably due to the faulty action of the filter. The filter is constructed as shown in Fig. 1, consisting of a 10-foot length of 15-inch wrought iron pipe

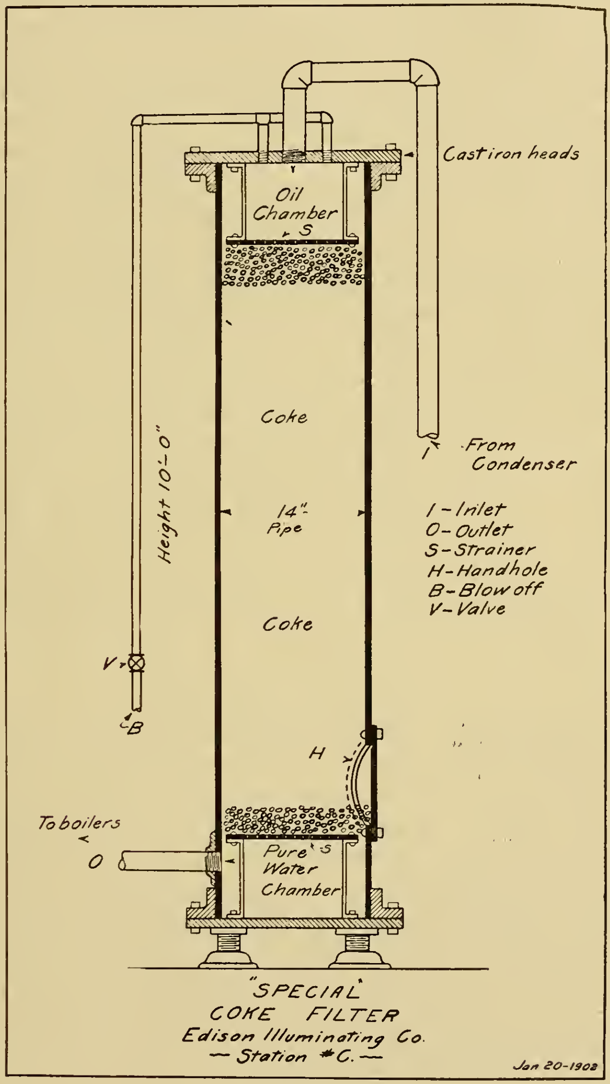



FIG. 1.

with flanged ends. A settling chamber is provided at the top and bottom and the coke is closely packed in the intervening space between these chambers, strainers being provided to allow free movement of water from chamber to chamber, but confining the coke to

the central portion of the filter. A hand hole at the bottom, and the removable top, furnish means for cleaning and refilling with fresh coke. The oily condensation enters at the top and when purified finds exit at the bottom. The blow-off taps into the upper chamber for the purpose of moving surplus free oil which collects there. This blow-off is usually operated at intervals of two hours. The filter is operated under pressure due to the column of tower water, 30 feet high, or about 15 pounds pressure. The size of coke used is average pea, varying from $\frac{1}{2}$ to 1 inch outside dimension. The discharge from the blow-off consists of considerable quantities of heavy black oil and much oil in the shape of emulsion, but not so easily detected on account of its light color and extreme dilution by pure condensed steam. An examination of the filter at the time of renewal of coke reveals the entire interior heavily lined with black oil, while the coke itself, especially at the top, is also entirely coated with the black oil. A shorter run would doubtless leave the lower layers of coke somewhat freer of the oily coating than the top layers, as the zone of greatest activity gradually descends from top to bottom. It is apparent that the presence of part of the oil which found its way into the boilers was due to overworking the filter, but subsequent experiments prove the filter to be entirely capable of freeing the condensation of oil in the form of emulsion.* The oil used in the engine cylinders is a special brand manufactured by Wilson, Clark & Company, Cleveland.

## EXPERIMENTAL WORK.

In searching for results of previous work along this line it became evident that the actual separation of entrained oil had never been obtained on a large scale either by mechanical separators or by chemical means. Several forms of water-purifying apparatus, however, separate oil in small quantities, together with other chemical impurities, but they do not attempt to purify condensation or dirty drips from the engine. It was then apparent that experimental work was necessary to determine the nature of the mixture, whether mechanical or chemical. The apparatus shown in Fig. 2

*The emulsion above mentioned is a mechanical mixture of the most intimate nature of oil and condensed steam.

When uncontaminated by black or free oil, the emulsion presents the appearance of a milky, opalescent liquid with a slight greenish-yellow tinge.

Samples drawn from engine reheater traps on the exhaust system are extremely dense and of more pronounced color than samples from the condensation, which contain such a large percentage of pure condensed steam that, although no color is apparent, the liquid still retains its milky or opalescent appearance.

was then constructed with a view to furnishing the greatest latitude possible in experimental work. Two observation cylinders of heavy white glass, fitted with brass heads and rubber gaskets, furnished means of observing whatever changes and reactions took place from time to time. Each head was tapped with a 1¼-inch nipple and furnished with air-tight gauge cocks, the cylinders being interconnected, as shown, with an opening for pressure or vacuum gauge. In one of the cylinders was inserted a steam coil of brass tubing and a thermometer cup. The whole was clamped together by two white oak heads and 5-inch bolts, the upper and thinner head being reinforced by 1¼-inch angle iron, which furnished great stiffness and made possible an equal distribution of stress between bolts. This was quite necessary, as the slightest irregularity in calibrated distance from head to head resulted in the opening up of one gasket or both under pressure. This apparatus proved capable of withstanding 90 pounds steam pressure, and would carry 60 pounds air pressure for 40 hours, with a drop of 10 to 15 pounds.

With this apparatus the following experiments were performed to determine the effect upon clear emulsion of:

(*a*) Pressure.
(*b*) Temperature.
(*c*) Vacuum.
(*d*) Aeration.
(*e*) Chemicals.
(*f*) Time element.

The emulsion was admitted by a funnel until the cylinder was about half full, the pressure being controlled by valves and distributed as desired between the cylinders as indicated by the gauge on the header.

RESULTS.

(*a*) Cylinder No. 1 half filled with stock emulsion obtained from trap on high pressure exhaust, temperature 210 degrees Fahr. at start. Air pressure gradually applied from 0 to 65. No disintegration at the end of 3 hours. Left same at 50 pounds for 16 hours. Slight deposit of oil on side of cylinders.

(*b*) 1. Hot sample emulsion at 0 pressure. Admitted live steam at bottom cock for one-half hour. Temperature 212 to 215, according to velocity of entrance. No perceptible change in conditions— same after 12 hours standing.

(*b*) 2. Hot emulsion subjected to 50 pounds initial air pressure. Also ram steam through coil for 1½ hours. Pressure, 65 pounds. Temperature 265 degrees Fahr. at end of test. Decided deposit of heavy black oil on glass walls. Solution greatly clari-

fied, though still somewhat milky and discolored from metal pipe. Allowed to stand, and filtered. Filtrate perfectly clear and free from oil.

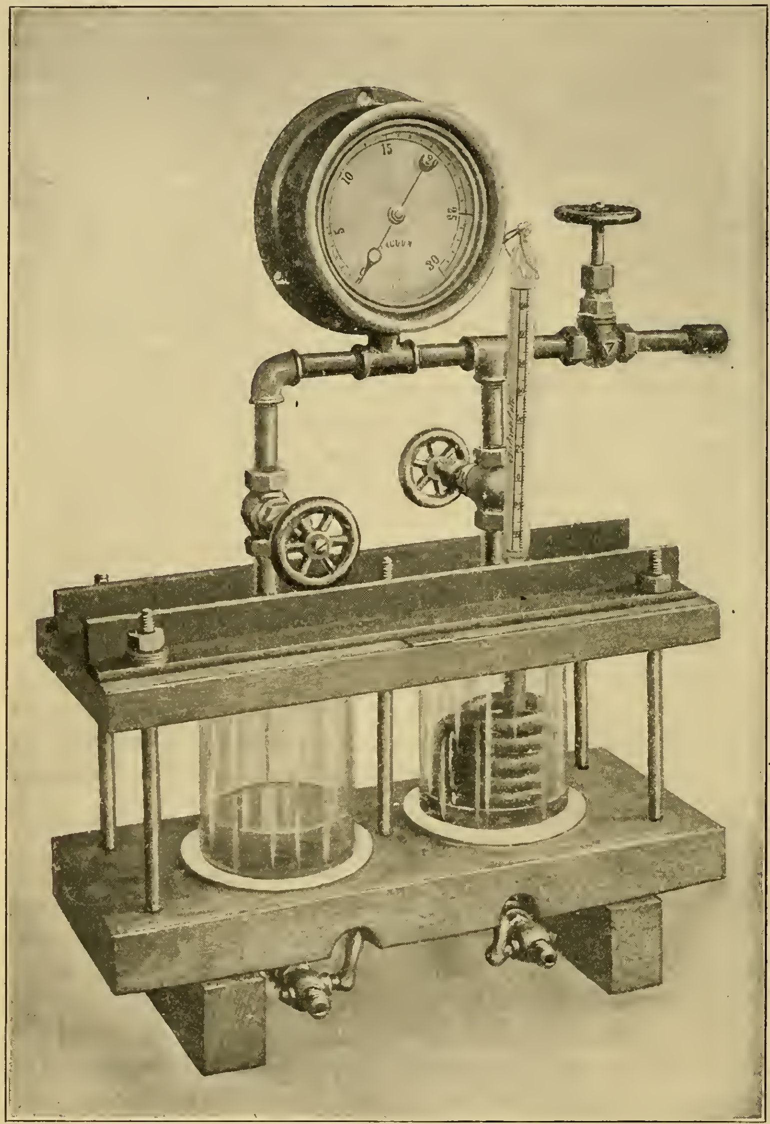


Fig. 2.

(*b*) 3. Sample emulsion hot from engine. Subjected to 50 pounds initial air pressure. Admitted live steam at the bottom cock, raising pressure to 80 pounds and temperature to 280 degrees

Fahr., beyond which ebullition became too violent. At the end of experiment there was a heavy deposit of black mineral oil on glass walls. Solution quite clear. Filtered, filtrate clear as crystal. Stood two days; slight deposit of iron oxide in the form of yellow precipitate; no traces of oil.

(*c*) Subjected hot and cold emulsion to 25-inch vacuum for 1½ hours. No change.

(*d*) 1. Aerated hot emulsion until cold at 50 pounds pressure. No results.

(*d*) 2. Aerated cold emulsion at 50 pounds pressure and at atmosphere by forcing air into the bottom. Very slight deposit.

(*d*) 3. Aerated hot sample at 24-inch vacuum for 1 hour. Very slight deposit.

(*e*) Cold sample at 0 pounds pressure. Injected strong solution of tri-sodium phosphate. Aerated slowly for ½ hour. No deposit.

(*f*) Sample drip from exhaust head of engines running non-condensing. Stood 30 days. Oil coagulated perceptibly in form of a creamy curd of slightly less specific gravity than water. No perceptible change in the body of liquid.

The inference to be drawn from these experiments is that, of all means thus far available, the application of higher temperatures is the only mechanical means of coagulating and separating entrained oil in the form of emulsion. This method, however, is the most inconvenient of all the mechanical methods, as it involves a live steam feed water purifier and oil filters combined, of sufficient capacity to handle the total condensations plus losses. It will also be at once recognizel as the operation which takes place in the interior of the boiler, when under pressure, the oil being forced out of its entrained condition by high temperatures and deposited on the heating surfaces of the boiler, thereby seriously reducing its operative efficiency.

An investigation into the chemical means of purification became at this point advisable. Before taking up this work, the sampling apparatus was constructed, as shown in Fig. 3, for the purpose of drawing out samples of liquid or steam as they occur under normal working conditions in the exhaust main of the plant. The pipe section represents the 15-inch exhaust main conveying exhaust steam from two 400-horse-power engines to the condenser. Fig. 6 shows the point of application of the sampling pipe to the exhaust main. A 2-inch hole was tapped in the top of the pipe at a point about 15 feet from the condenser intake and a special packing box inserted as a plug. Through this box a ⅜-inch brass sample

pipe could be moved up and down at will, thus allowing the removal of samples of exhaust at different levels in the main. A specially constructed hand pump, capable of producing a 25-inch vacuum, was used to work against the running vacuum, which usually was required to be lowered to 20 inches, in order to give sufficient difference in pressure to obtain samples of any volume.

The glass observation flask (e) was used to catch all the liquids while the steam was condensed in the cooling coil G, and caught in flask (F). When the apparatus was not in use, a $\frac{1}{4}$-inch pipe plug was inserted in place of the sample pipe, thus preventing any leak and the necessity of removing the larger plug during operation. The sample pipe being graduated in inches enabled observations to be made at different elevations in the interior of the pipe. In exploring the interior during operation three facts became at once apparent:

First. No oil occurred in the free or normal state as it was injected into the cylinder of the engine.

Second. The exhaust steam from the top of the pipe to within a variable distance from the bottom (0-4 inches) was pure steam, uncontaminated by emulsion, in a vaporous state.

Third. Samples of liquid lying or moving along the bottom of the pipe were, without exception, emulsion of a light greenish-yellow tint, uncontaminated by black oil. They apparently were the same mixture that was obtained from the high-pressure exhaust of the engine, minus a small amount of black oil, which is removed from the condensing system by a steam trap located at the lower end of the receiver chamber of the engine reheater. A question here arises relative to the appearance of the black oil in the filter, shown in Fig. 1. This oil did not appear in this form in the exhaust main, nor did it appear in experiments (*c* and *d,* vacuum and aeration) previously described, where conditions of temperature and pressure were reproduced from those which obtained in the condenser proper.

Two explanations are apparent.

First. The uncombined oil which does not show in the sampling apparatus is confined entirely to the dry sides of the pipe, where it is forced along by superficial friction, due to the enormous velocity of the passing steam.

Second. The separation in the condenser may take place under different conditions than those reproduced, the sudden condensing of the steam having possibly some effect at present unknown. The first supposition is somewhat invalidated by the fact that if free oil existed on the sides of the pipe, it would certainly

tend to gravitate to the lower surfaces, if not to the basin, of the pipe, and there come within range of the sampling pipe. The second supposition seems the more probable, but this point can be better elucidated by further experiment. Concerning the presence of emulsion, experiment (*b,* temperature) proved that the mineral oil was transformed from the emulsion to the free state only by high temperatures and high pressures, the latter being a seemingly unimportant factor in the process. These conditions correspond to the conditions obtaining in the high-pressure cylinders, but not in the low-pressure cylinder. Under the supposition that emulsion is formed in the low-pressure cylinder, the non-appearance of free oil in the exhaust main seems to indicate that the limiting temperature of separation is never reached, and, consequently, that the trap on the reheater should remove all free oil escaping from the high-pressure cylinder, and thus free the system

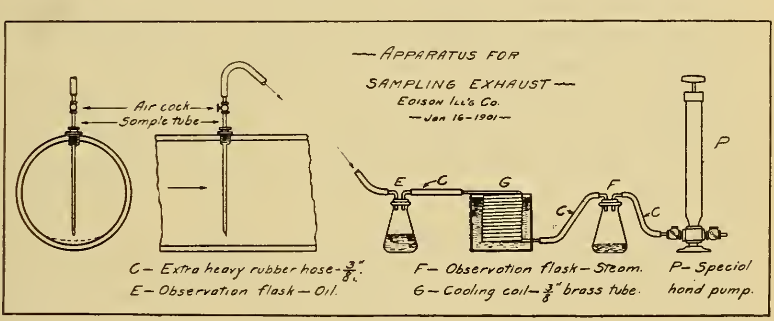



FIG. 3.

of this objectionable feature. The uncertainty of performance in the condenser, however, necessarily deprives this supposition of its main value. A further point not yet mentioned concerns the effect of pockets in the exhaust system. The first experiments with the sampling apparatus in the location shown in Fig. 6 revealed a depth of 3 to 3½ inches solid emulsion in the basin of the exhaust main. Subsequently the condensing system was shut off, and shortly thereafter the contents of the exhaust pipe sampled. It was found to contain pure vapor to within 5 inches of the bottom of the basin, and solid emulsion thereafter. This was due to the presence of a pocket in that part of the pipe, in which had accumulated 5 inches of liquid, thus reducing the effective area of the exhaust main 38 per cent. During operation the upper surface of this body of liquid would probably assume a concave form, thus accounting for the lesser depth noted at this time. As the exhaust pipe had been in constant use for nearly a year, it is probable that

any additional body of liquid from the engine would be swept through to the condenser, as the depth of $3\frac{1}{2}$ inches could easily have collected in a few hours. This, then, being the limiting depth, an increase of which would be prevented by the increase in velocity of the passing steam. The foregoing observations seem to point to the necessity of an efficient separator, located at the lowest point in the main exhaust line.

This question will be taken up later.

### CHEMICAL TREATMENT.

A consultation of the various authorities upon practical chemistry indicated in a general way the method of chemical treatment for purifying liquids contaminated by oleaginous matter.

### LUBRICATING OILS.

All oils ordinarily used for lubricating purposes are composed of animal, vegetable or mineral oils, either in the pure state or in the form of a mixture of various percentages of each separate constituent. The oils most commonly used for this purpose are: First, mineral—heavy, medium, light or paraffin (petroleum distillates) ; second, vegetable—olive, rape and castor; third, animal—lard, neat's foot and sperm; fourth, resin oils sometimes used as adulterants, but are very gummy in their nature.

The proportions in each constituent in compounded oils varies entirely with the work for which the lubricant is intended, the heavy oils being used where great pressure or high temperatures obtain, and the lighter oils for light-running machinery. Valve, engine and dynamo oils are usually compounded principally of mineral oils and varying amounts of lard, tallow and rape oil, or even solid tallow. All fixed or fatty oils may easily be recognized and distinguished from mineral oils by their inclination to saponify in the presence of a base, while the mineral constituents remain absolutely inert in the presence of either acid or alkali, and exhibit no tendency to oxidize, as do fixed oils. Fixed or fatty oils are composed of fatty ethers or esters, formed by the union of an alcohol with a fatty acid radicle; thus glyceryl $C_3\,H_5$, which is the radical of glycerol or glycerin $C_3\,H_5\,(O\,H)_3$ combines with an acid radical R to form the resultant oil $C_3\,H_5\,R_3$ (olein, stearin, palmitin).

$$C_3H_5\,(OH)_3 + 3(R) = C_3H_5(R)_3 + H_2O$$

Inorganic analogue $2\,KOH + H_2(SO_4) = K_2(SO_4) + 2\,H_2O$.

*Saponification* is the reverse of this reaction, viz, the splitting up of an ester or ether into an alcohol and a fatty acid, and may be brought about either by hydrolysis (heating with steam under

pressure) or by the presence of a strong base. As an example of this disintegration:

(a) Olein + water (steam) = glycerol + oleic acid

$$C_3H_5(C_{18}H_{34}O_2)_3 + 3H_2O = C_3H_5(OH)_3 + 3C_{18}H_{34}O_2.$$

This reaction takes place in steam cylinders, forming metallic soaps and salts at the expense of cylinder walls, stuffing boxes, etc.

(b) Olein + 3KOH = glycerol + 3 (potass. oleate)

$$C_3H_5(C_{18}H_{34}O_2)_3 + 3KOH = C_3H_5(OH)_3 + 3K(C_{18}H_{34}O_2).$$

Here the alcohol is liberated (as also by hydrolysis), while the acid combines with the strong base to form soap. These soaps are easily decomposed by mineral acids, thus:

Potass. oleate + H C L = K C L + oleic acid) =

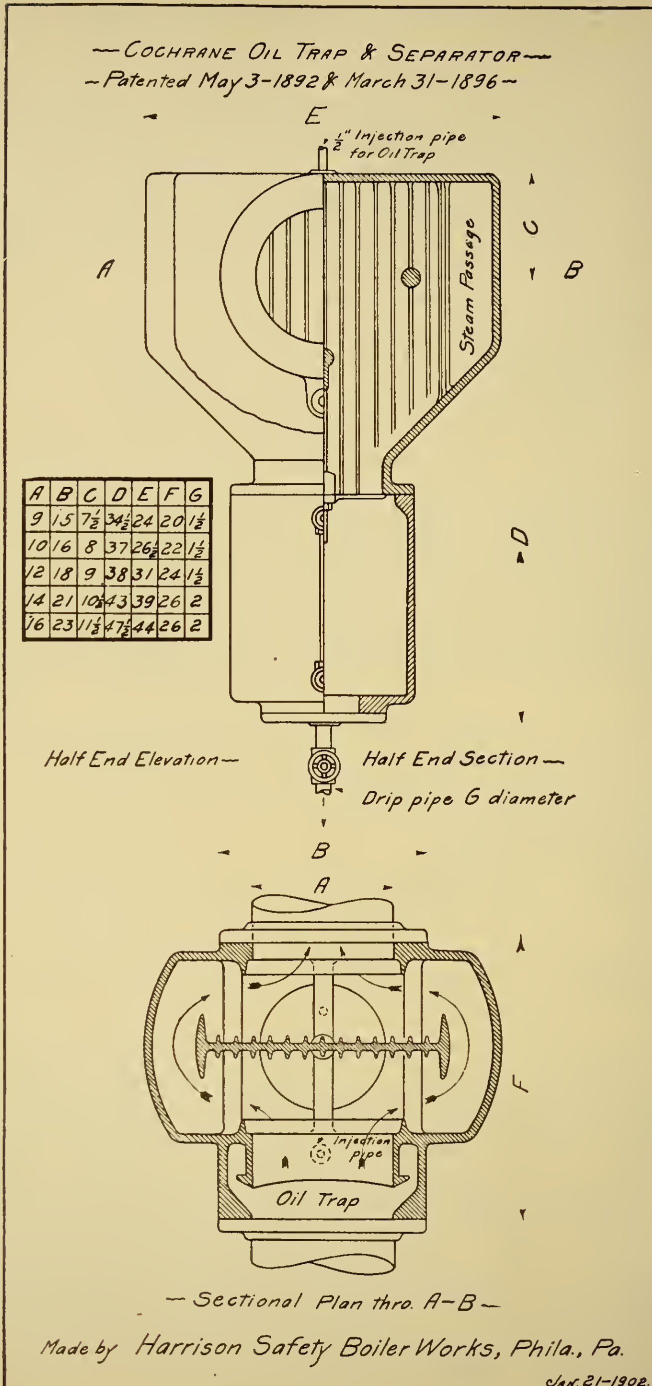
$$(K(C_{18}H_{34}O_2) + HCl = KCl + C_{18}H_{34}O_2,$$

the salt going into solution, while the fatty acid is set free. Mineral oils, if boiled with K O H, suffer no change, while fixed oils or esters saponify, forming soaps and glycerol, which may be readily washed away. These reactions furnish simple and accurate means of analyzing quantitatively the various brands of engine and dynamo oils in use. The result of using oils containing esters of fatty acids is shown in the following analysis of cylinder deposits from a large compound engine cylinder (high pressure)*:

| | | Per cent. |
|---|---|---|
| Moisture | | 13.10 |
| Oils sol. in ether, | Animal | 8.15 |
| | Mineral | 7.86 |
| Hydrocarbons insol. in ether | | 1.67 |
| Soap | | 2.10 |
| Oxide iron and aluminum | | 6.81 |
| Fixed carbon | | 2.71 |
| $Si\ O_2$ | | 3.65 |
| $Ca\ CO_3$ | | 43.22 |
| $Mg\ CO_3$ | | 10.17 |
| Undetermined | | 0.44 |
| | | 100.00 |

In casting about for chemical means of separating oil in the condensing plant previously described the idea of saponification naturally suggested itself, in the hope that an insoluble soap might be found which would at once give the desired reaction. Of these the calcium, aluminum and magnesium soaps seemed the more promising, and would indeed have proved successful if pur-fixed oils had been used. As no saponification could be detected, the oil itself was examined by the method indicated above, and found to be pure mineral oil, consequently unaffected by acids and bases alike.

*Stillman, *Engineering Chemistry.*




| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| 9 | 15 | 7½ | 34½ | 24 | 20 | 1½ |
| 10 | 16 | 8 | 37 | 26½ | 22 | 1½ |
| 12 | 18 | 9 | 38 | 31 | 24 | 1½ |
| 14 | 21 | 10½ | 43 | 39 | 26 | 2 |
| 16 | 23 | 11½ | 47½ | 44 | 26 | 2 |

FIG. 4.

Samples of the emulsion subjected to the most sensitive test proved entirely inert, and showed conclusively that the oily mixture obtained from the engine drips and exhaust main is a mechanical mixture of water and mineral oil, but, withal, so complete a mixture as to appear like a chemical one, showing no evidence of oily or other foreign matter in mechanical suspension.

### COAGULATION.

The emulsion having thus far resisted all attempts at chemical disintegration, a series of coagulative tests were made,* employing successively fuller's earth, powdered marl ($Ca\ Co_3$), slaked lime and a double treatment of alum and $Na_2\ C\ O_3$.

The fuller's earth and calcium compounds produce the most gratifying results. In each case the chemicals were mixed with water to the consistency of thin paint, and, in this state, added to the sample of emulsion, the whole being then agitated for a short period and allowed to settle. With the calcium compounds coagulation occurred almost instantly, and a milky-white curd of considerable volume and weight settled slowly to the bottom, leaving the liquid quite clear, although slightly alkaline. Fuller's earth produced the same results after a longer period of agitation and settling, with the exception that after the coagulated oil had settled to the bottom in the form of a grayish-brown sludge, a fine, cloudy precipitate still hung in suspension for some time, which finally settled also, leaving the solution clear and without acid or basic reactions.

It was found that freshly prepared milk of lime, used as a coagulator, imparted to the filtrate or clear liquid a much stronger basic reaction than powdered chalk or marl. It was also found that the solid constituents of the lime mixture were alone responsible for the coagulation, which was proved by treating emulsion with pure lime water decanted from a quantity of milk of lime, in which this solid matter had been allowed to settle. No coagulation was observed.

### WATER ANALYSIS.

In order to definitely ascertain which of these reagents may be most successfully applied to any particular case of power station operation, the constituency of the feed water in its natural state should be considered. A chemical analysis of the water of the Detroit River by the Detroit Water Board reveals various impurities, as indicated in the table below. These analyses are not recent, but show a fairly uniform constituency.

*At the suggestion of Professor Campbell, of the University of Michigan.

ANALYSIS DETROIT RIVER WATER—WATER BOARD.

| Date of Observation. | | 1861. | 1872. | 1879. | 1879. |
|---|---|---|---|---|---|
| Ingredients. | | Grains per U. S. Gal. | | | Pts. per Million. |
| Calcium sulphate. . . | $Ca\ SO_4$ | 2.53 | 0.70 | 1.043 | 17.89 |
| Calcium bicarbonate . | $Ca\ H_2\ (CO_3)_2$ | 1.652 | 4.11 | 3.353 | 57.49 |
| Magnesium bicarbonate | $Mg\ H_2\ (CO_3)_2$ | . . . . | 0.66 | 1.209 | 20.73 |
| Potassium chloride . . | $K\ Cl$ | 0.145 | . . . . | . . . . | . . . . |
| Sodium chloride . . . | $Na\ Cl$ | 0.361 | 0.24 | 0.229 | 3.93 |
| Sodium carbonate. . . | $Na_2\ CO_3$ | . . . . | 0.32 | 0.394 | 5.75 |
| Magnesium chloride . | $Mg\ Cl_2$ | 0.185 | . . . . | . . . . | . . . . |
| Aluminum phosphate . | $Al_2\ PO_4$ | 0.034 | . . . . | . . . . | . . . . |
| Iron carbonate . . . . | $Fe_2\ CO_3$ | 0.508 | . . . . | . . . . | . . . . |
| Potassium sulphate . . | $K_2\ SO_4$ | . . . . | . . . . | Trace. | Trace. |
| Alumina. . . . . . . | . . . . . . . | 0.593 | . . . . | 0.241 | 4.13 |
| Silica . . . . . . . . | . . . . . . . | 0.263 | 0.28 | 0.306 | 5.24 |

PURIFICATION.

The foregoing table shows the principal scale-forming ingredients of Detroit River water to be $Ca\ H_2(C\ O_3)_2$ 57.49 parts per million, $Ca\ So_4$ 17.89 parts per million, and $Mg\ H_2(C\ O_3)_2$ 20.73 parts per million.

It is therefore necessary to adopt some means of relieving the boilers of this deposit. This may, of course, be accomplished by means of:

First. Live or exhaust steam purifiers, in which the water is heated by steam to a temperature at which the $CO_2$ dissolved in the river water is driven off, thus depriving the bicarbonates of their solubility and precipitating them in appropriate receivers. The extent of this reaction will depend upon the temperature of the steam, and, in order to affect the deposition of sulphates, the process must be supplemented by further treatment with soda ash or other compounds.

Second. Porter-Clark process. This is entirely chemical and highly recommended by authorities on water purification, some advising single and others a double treatment, according to the constituency of the water and the conditions of treatment. In this process the bicarbonates are reduced to insoluble carbonates by a treatment of milk of lime, which is simply the liquid obtained by slaking freshly burned lime.

The sulphates are treated with soda ash to form soluble $Na_2\ So_4$ which remains in solution, while the insoluble carbonates are thrown down.

These reactions may, of course, take place inside the boiler, with a result that more frequent cleanings and blowings-off must be resorted to in order to prevent undue concentration and collec-

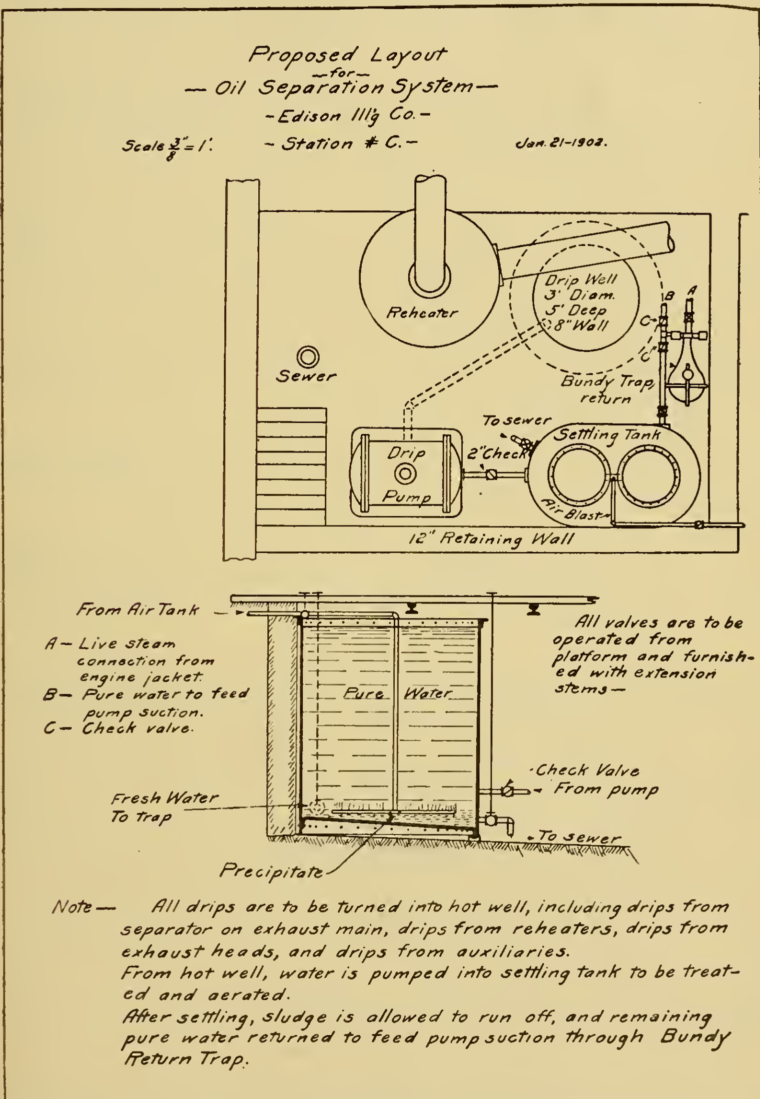



FIG. 5.

tion of the sludge. The extent of this concentration may be judged from the quantity of calcareous deposits in the cylinder noted in the above analysis, this having been carried over during priming of boiler. A proper system of treating would involve mixing and

settling tanks of considerable size, as the reactions are necessarily slow, from one to two hours being required for their completion, unless an extra quantity of reagent be used to hasten them. In this case filters must be employed to remove the precipitates from suspension.

Third. Other reagents and purifiers are, of course, employed, including caustic soda, tridodium phosphate, galvanic batteries and various brands of vegetable compounds (for the manager), but these are not essential to the subject in hand.

In view of the success of the lime treatment it is apparent that the same material may be advantageously used as an oil coagulator, the two systems being operated with a common reagent. Other reasons for the selection of lime are:

First. It acts much more powerfully and quickly in precipitating oily matter in suspension, thus shortening the time necessary to complete the reaction.

Second. The hydroxide $Ca\ (O\ H)_2$, which invariably goes into solution with the water, is a highly desirable substance, and may be made a factor in the water-softening process above described.

Third. The oil precipitate is much lighter and more mobile than that produced by the fuller's earth, and therefore easier to separate by filtration.

In a condensing plant where it is possible to make use of condensation for feed water, it is evident that the softening process may be largely dispensed with. Assuming the original contents of the boiler to be free from carbonates and sulphates, and condensation to be entirely free from oily matter, either in the free or emulsion form, the small amount of fresh water necessary to add to the water cycle to supply leakage losses must of necessity be but a small proportion of the total volume of water in the boilers, and require little treatment. This fresh water supply would, of course, be greatly augmented if non-condensing auxiliaries were operated from the main battery of boilers, in which case the softening process would have to be applied to all fresh water entering the boilers.

In the event of the main power system being operated independently of auxiliaries, the pure water cycle may be continued indefinitely by the addition of an amount of *purified* water sufficient to replace the above-mentioned leakage losses. This would, of course, require separate treatment of feed water for auxiliary boilers, which, however, would be necessary in any case, unless condensing auxiliaries were used.

## SEPARATORS.

A consideration of the results obtained with the apparatus shown in Fig. 3 makes it at once apparent that the chemical treatment of the entire condensation is unnecessary, for the reason that but a small proportion out of the total volume of condensation is oily emulsion, and this proportion, therefore, only requires treatment for entrained oil. If, then, an efficient separator be located in the exhaust main at a convenient spot, which will trap all emulsion and impurities, whatever then reaches the condenser should be pure steam, and after condensation may be pumped directly back to the boilers as pure feed. It is also apparent that a special trap must be provided to remove entrained liquid from the separator under working vacuum. Of the three separators on the present market, Cochrane, Baum and Bundy, the first and second seem to present the more desirable features, viz:

(a) Velocity of steam through passages is kept at a low value by the designers. This feature is, however, acquired at the expense of floor space.

(b) An oil ring or annular pocket is provided, extending entirely around the exhaust pipe entrance on the engine side of the separator, for the purpose of arresting whatever heavy oil may creep along the walls of the pipe. Fig. 4 shows section of Cochrane separator.

(c) Extreme simplicity in absence of parts liable to become clogged by foreign matter (shreds of packing, etc.). In the case of the Bundy separator, in which entrained liquid is arrested by a series system of rectangular staggered grids, the net area or aggregate port opening of each grid is approximately equal to the area of the pipe, which would theoretically cause no change in velocity of the steam. But the design and location of these grids results in a large difference between actual and effectual port opening, necessitating the introduction of other grids in the form of a series system to secure a certainty of results. This multiplicity of baffles in the direct line of steam current cannot but be operative in introducing a considerable resistance in order to decrease the velocity of steam to a point where it will release entrained oil, water, etc. The makers, however, claim that tests with a sensitive gauge failed to reveal any appreciable drop in pressure over this grid work.

## VELOCITY OF EXHAUST.

Three cases are calculated below, of which (a) and (c) are from actual operation:

(*a*) corresponds to full loaded engines, vacuum about 20 inches, 900 horse power.

(*b*) also at full load, provided 26-inch vacuum could be maintained, 900 horse power.

(*c*) Average morning load—full load on one engine, 400 horse power.

DATA.

Diameter exhaust main, 15 inches; area, 1.23 sq. ft.

Average vacuum, 19.74 at 900 horse power; 25.85 at 400 horse power.

Steam consumption engine, 17.43 pounds, full load (by test.)

Volume, 1 cubic foot steam; 72.50 at 20-inch, 173.23 at 26-inch vacuum.

(*a*) $\frac{900 \times 17.43 \times 72.50}{1.23 \times 60} = 15{,}400$ feet per minute.

(*b*) $15{,}400 \times \frac{173.23}{72.50} = 36{,}800$ feet per minute.

(*c*) $\frac{400 \times 17.43 \times 173.23}{1.23 \times 60} = 16{,}400$ feet per minute.

The distinctive features of the three separators are:

Cochrane.—First. An annular oil ring on the engine side, the surface of which is wetted by a small stream of water entering at the top of the annulus.

Second. Sufficient sectional area for steam passages to reduce the velocity of steam to about 18,000 feet per minute, above which, it is claimed, oil will not be entirely released from the passing steam.

Baum.—First. A hollow ribbed baffle, located in the middle of the steam space of the separator and kept at a low temperature by circulation of water in the interior, which causes the ribbed surface to be covered with a film of moisture, which, it is claimed, isolates oil from the impinging steam.

Second. The steam current is allowed an easy turn around the baffle, and is not confronted by a flat or normal surface, from which the impinging liquid might rebound into the steam current.

Bundy.—A series system of removable grids, which may be inspected and cleaned from time to time, thus giving an indication of the conditions existing in the exhaust mains and preventing foreign matter (such as packing, fiber, etc.) from clogging up the condenser passages. As to the relative merits of these oil separators, there is, unfortunately, no exact data available. In a test of a steam separator* of the baffle plate design (such as the Austin),

*Trans. A. S. M. E., 1899. Specific gravity. Oil injected into steam current, 0.830, at 60° Fahr.

Mr. Charles H. Emory gives the following data, determined from careful laboratory determination of oil-separating properties:

| Run. | Pounds Oil Injected. | Pounds Mixture Removed. | Sp. Gr. Mixture. | Per cent. Oil Recovered. |
|---|---|---|---|---|
| 1 | 1.86 | 2.81 | 0.930 | 58.6 |
| 2 | 3.05 | 5.10 | 0.942 | 53.0 |
| 3 | 0.14 | 1.82 | 0.940 | 42.0 |
| | | | Average, | 51.2 |

It is evident that any design of separator which does not completely arrest entrained liquid will not operate satisfactorily under vacuum conditions noted above.

### TRAPS.

The Bundy automatic trap, with steam-balanced overflow valve, seems to be the only apparatus on the present market capable of automatically removing entrained oil or water from vacuum systems, and is used in connection with both Bundy and Cochrane separators. It may be located in any convenient position where sufficient difference in level between separator and trap may be obtained to permit of the transfer of entrained liquid from the former to the latter by gravity.

A form of hand-controlled trap much in use consists of a closed receiver, fitted with an internal float, which operates a whistle or electric alarm in order to notify attendant of the proper time for discharging receiver. This is accomplished by a three-way valve, which, when reversed by hand, cuts off communication with vacuum system and admits live steam into the receiver, expelling the contents by pressure through a check valve at the bottom.

### DRIP SYSTEM.

In applying this system of oil separation to a condensing plant, it will be necessary to convey all oily drips from engine, pump, reheater and separator traps to an appropriate drip well or tank installed in some central and convenient location (such as a reheater pit).

This method of collecting drips is usually applied to pure steam drips only from steam mains, while the foul drips are turned into the sewer. This, of course, should be continued independently of the purification system, as it would be unprofitable to mix pure and oily drips and then treat the whole for oil.

### ESTIMATION OF DRIP.

In order to ascertain the total amount of oily liquid to be purified, engines and auxiliaries were run non-condensing on one exhaust head and the drip therefrom collected and weighed. During

the succeeding day, at corresponding time and load, auxiliaries were run alone on this same exhaust head. Weighing drip as before, the net engine drip was obtained by subtraction.

| | |
|---|---|
| Duration of test, 1 hour. | |
| Net average load, kilowatts | 191 |
| Total drip (1 engine and auxiliary), pounds | 450 |
| Total drip, auxiliary | 70 |
| Net engine drip | 380 |
| Estimated engine drip, at 600 kilowatts, pounds | 1,200 |
| Estimated total | 1,420 |
| Estimated reheater drip (2 engines) | 450 |
| Total, oily drip per hour, pounds | 2,870 |
| Or, gallons | 344 |
| Jacket steam (2 engines), pounds | 833 |
| Pure steam condensation, pounds | 639 |
| Total, pure drip per hour | 1,472 |
| Or, gallons | 176 |
| Total station, gallons | 520 |

The pure drips were determined at a previous test of the entire plant, and are nearly constant.

PURIFICATION PROCESS.

The special apparatus required for treating oily water consists of a mixing tank, a small pump, return trap and filter of the type previously described.

Fig. 5 shows the general construction of the tank, built of No. 10 sheet steel, with sloping or conical bottom, this being necessary for discharging the precipitate into the sewer.

An agitator is provided for thoroughly mixing liquid and reagent before precipitation, and consists of a double-pipe ring, with numerous holes drilled on the upper surface, and supported near the bottom of the tank in a horizontal position. It is to be supplied with compressed air, which is available in every up-to-date plant. A check valve is inserted between the tank and pump; also on each side of the return trap. The sludge outlet is controlled by gate valve, and the pure water outlet and aerator by globe valves.

The method of operation is as follows:

First. Tank is filled from well by small pump.

Second. Coagulator added from platform above.

Third. Air valve opened and aeration continued for a predetermined interval.

Fourth. After precipitation the sludge valve is opened, and closed when pure water appears at the outlet.

Fifth. Trap valve opened, allowing contents of tank to be forced through filter into the pump suction of boiler feed pumps.

The amount of time required for the complete operation can only be determined by trial in each particular case, and obviously depends entirely upon the amount of oily matter to be removed;

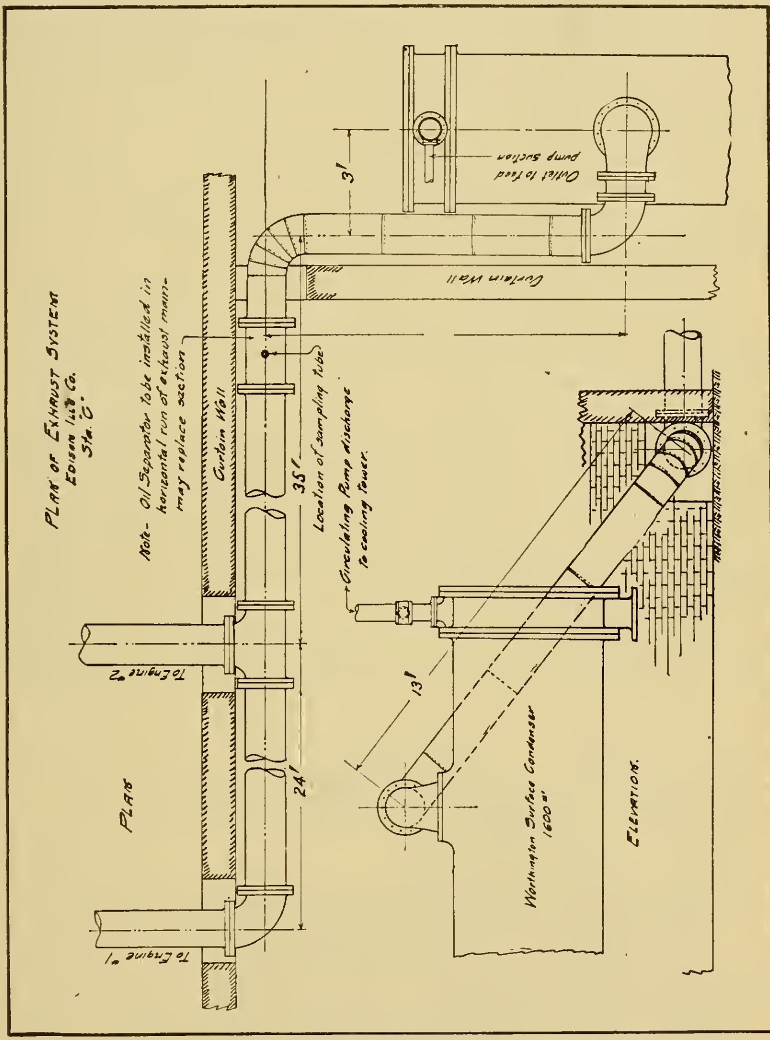


FIG. 6.

this in turn determining the amount of coagulator to be added. The lime liquor is most easily prepared by slaking a large quantity of fresh lime in a wood or brick receptacle, from which measured quantities are withdrawn for each reaction, proper precaution being taken to insure uniform consistency.

Judging from the results of laboratory experiments, a period of aeration of three to five minutes should be ample for completing mixture, and ten to fifteen minutes for settling, although this time may be shortened, if necessary, as the filter will absorb the small amount of fine precipitate which is not thrown down with the first precipitation of sludge.

The feasibility of this system of purification is, of course, determined entirely by the cost of city water treated for scale-forming impurities, as compared to the cost of the process, including attendance and repairs.

In the event of pure water being employed for continuous operation, the methods of supplying same to system are:

First. Softening by chemical means a sufficient quantity of fresh river water.

Second. Purifying the same amount of oily drip.

The latter is obviously the better method, as it returns to the boilers pure water, while the former returns softened water containing $Na_2\ So_4$ in solution.

With the low water rate of the city of Detroit, 2¼ cents per thousand gallons, it is doubtful if the system would be a profitable investment, unless, as before mentioned, it is desired to operate on a pure water cycle entirely. The separator on exhaust mains should, however, be retained in any case, thereby enabling a large percentage of condensation to be saved, irrespective of the drips. With higher water rates for large condensing systems, where waste from drips would be considerable, it is probable that the system could be employed to great advantage, both from the standpoint of saving in water bills and boiler maintenance.

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## CONDENSING ENGINE PRACTICE.

By Alex. Dow, Member Detroit Engineering Society.

[Read before the Society, January 24, 1902.*]

Last winter, when I related to the Society my experience with condensers and cooling towers, I stated that during the coming year (that is to say, the year now past) I expected to gain information on several points of condenser practice, and that this winter I would put the same at the service of the Society. Some of that information has been duly acquired and is about to be presented to you. Some other very desirable information has been out of reach during the twelve months because of divers circumstances which prevented my making the intended investigations. A little of the information which I desired is apparently going to remain out of reach indefinitely.

I expected to furnish you comparative figures showing the effect of increased height and increased surface in our Worthington cooling tower. I also expected to furnish you comparative results from the horizontal duplex air pump of the Worthington type and form a vertical single-acting pump. The carrying on of other work in our plants made it impossible to dispense with the Worthington tower long enough to make the proposed changes of height and surface, and these are therefore postponed until the present year. Delays in designs and pattern work, and later the machinists' strike, prevented the delivery of our single-acting air pump during the summer, and the change of pump also is postponed until the early part of this summer.

The vertical pump we selected is of a pattern new in the United States, and I will describe it later.

Mr. J. Rowland Bibbins this evening presents the information we accumulated regarding the elimination of oil from condensed steam.

We have had since my last talk a little more experience with cooling tower fans. I told you a tale of woe a year ago. The little that is to be added to that tale is that a curved blade, or so-called helical fan in a cylindrical draft tube has less backlash than a straight-blade fan, but is not by any means free from backlash. We put the new helical fan in the draft tube of our Worthington tower and rid ourselves of the icicle trouble by putting a steam jacket around the outside of the tube. The zone of reversed draft is appreciably narrower than it was when we used the straight-blade

*Manuscript received February 13, 1902.—Secretary, Ass'n of Eng. Socs.

fan; but the reversed draft is still there. As between fan draft and natural draft we have nothing to add to our former observation; namely, that natural draft is no cheaper in first cost than is fan draft for the same final water temperature. If you are going to cool the water with natural draft, you will need so much more tower to get a given temperature that you will more than offset the additional cost of the fan and its driving apparatus. Whether the natural draft will be the cheaper to operate depends on how much the power for auxiliaries and the power from main engines are relatively worth to you. It is very likely that your figures will come out even for either style of tower. The fault of the natural draft tower is, as I stated concisely last year, that you don't get a good draft until you have a bad vacuum. The draft depends on the water being heated enough to raise the temperature inside the tower above the temperature of the atmosphere. The difference of temperature necessary for a sufficient draft during most of the year is such as is only obtained when the circulating water is heated by exhaust steam of temperatures corresponding to relatively poor vacuums. In our electric light business we have the advantage that our heavy loads come at night and in the winter time, when the lower temperature of the external air permits good draft simultaneously with comparatively good vacuum.

Appreciation of this characteristic of natural draft towers has led to the production of some towers which are not enclosed at all, and to the evaporating surfaces of which the air has access from all sides, so that there is no regular draft at all. I have a report from the operation of one of these towers, but have no personal knowledge thereof. It is hardly fair to call this device a tower. It is a stack of mats or similar cooling surface, and I would suggest that the proper name for it is "cooling stack."

The home-made natural draft cooling tower at our Foundry Street Station, which was described last year by Mr. Bibbins, has been in operation during the entire twelve months. It is a commercial success. It was designed for approximately 500 engine horse power on a 20 pounds per horse power rating—that is to say, to take care of 10,000 pounds of steam per hour. To that extent it is a technical success. We have, however, acquired the habit of working it in the evening at about twice that duty. The surface condenser with which it is associated was furnished several years ago by Messrs. Worthington as an 800 horse power condenser on a 20-pound rating. It is of the Admiralty type, and has 1600 square feet of tube surface. Our latest test

was a 24-hour test, made by the Engineering Department of the University of Michigan. Of the results of this test only a few figures are of immediate interest. One fact, which was well brought out, is that the vaporization in the cooling tower is practically equal to the condensation. In this case it is in excess of 1.01 per cent. only. To generalize this statement, it means that for every pound of steam reduced to water in the condensing system

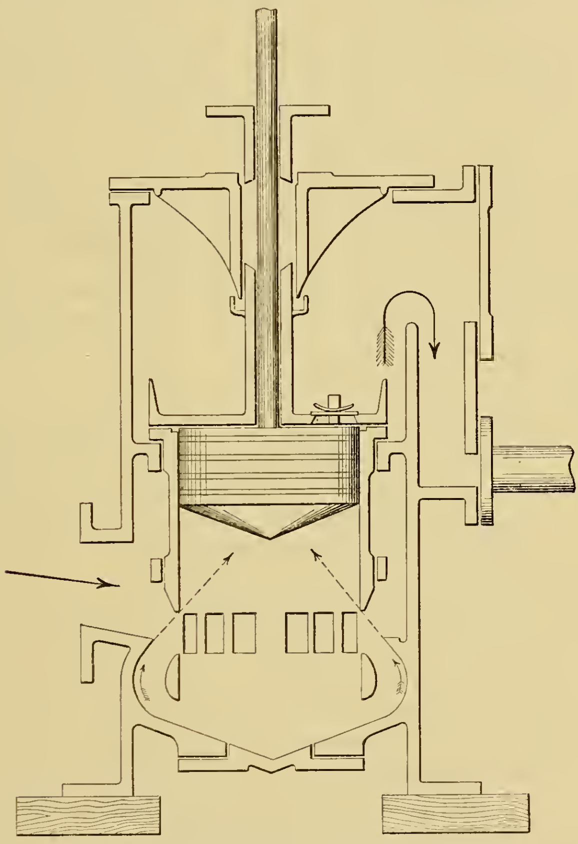


FIG. 1. EDWARDS PUMP AT TOP OF STROKE.

a pound of circulating water was evaporated in the cooling tower. This particular 24-hour test is merely a good illustration of a general rule; for all the cooling tower experience of which I have knowledge is that the amount of make-up water required by the tower is practically identical with the amount of condensation furnished by the engines. One would anticipate that there would be an excess of condensation because, while we recognize that the cooling of the water in the tower is chiefly by evaporation,

there must be some cooling by the transfer of heat from the water to the air. Considering the specific heat of air, it becomes obvious that this transfer is negligibly small in comparison to the heat required by vaporization of water, and we are justified in saying that the function of the air passing through a cooling tower is not to cool the water by contact, but is merely to sweep out the vapor given off by the water.

Another interesting observation is that the water circulated per hour, during the 24 hours, was on the average fifty times the weight of the steam condensed. The average hourly values are 293,536 pounds of circulating water and 5910.6 pounds of steam. This is not to be understood as meaning that we had any such quantity of water available for circulation as is figured. In common practice one does not use any more water in a cooling tower than is necessary to keep the circulating system filled. Some excess of water is convenient, and this can lie in the bottom of the tower or (when the tower is built on the ground level) in a tank underneath the tower. In this case the water in the system goes round about once in 10 minutes. The reserve is larger than usual, being intended to act as a reserve supply of feed water.

The heat balance which was got out by the gentlemen from the University of Michigan states that during this particular test the exhaust steam system lost about 20 per cent. of its heat by radiation. Let me make this statement clear before commenting on it. The quantity of circulating water was figured by counting the strokes of the pump. There is probably some error in this, as the pistons do not travel exactly the same distance at every stroke; but the value, I think, is not very far wrong. The condensation discharged from the condenser was accurately weighed. The temperature of the circulating water was taken as it entered the condenser and as it left the condenser. From the quantity of the circulating water and the differences of temperature, the heat units delivered to the circulating water were calculated. The heat units given up by the steam were calculated from the known weight of the condensation and its observed temperature, and from the observed temperature of the steam entering the condenser. According to these calculations the circulating water only accounts for 80 per cent. of the heat of the steam. The experts concluded that the remaining heat was lost by radiation. There are circumstances which make it likely that there was, in this case, a considerable amount of condensation due virtually to radiation. The temperature of the house was 61 degrees. The exhaust pipe from the engines to the condenser is comparatively

long, and located in a relatively cool portion of the house. The temperature of the steam entering the condenser averaged 134 degrees Fahr. It was considerably higher during some portions of the day. There would, therefore, be an appreciable loss by radiation from the long exhaust pipe and from the walls of the condenser. Moreover, observations taken at other times, and for another purpose, show that in the exhaust pipe there is always water traveling with the steam toward the condenser. The two engines which exhaust into the condensing system have their exhaust valves in the bottom of the cylinder ends, and these valves open in such a manner that any condensation lying in the cylinder at the moment of release will be swept out without having a chance to re-evaporate. Apropos of this observation, let me remind you that this location of exhaust valves is recognized as being important to engine economy, and that its assistance to that end is admittedly due to this instantaneous sweeping out of all condensation from the cylinder. The water which we find traveling in our long exhaust pipe is, therefore, initially (and I think, mainly) that resulting from cylinder condensation; to which is added the condensation due to radiation from the pipe. While, therefore, I question the value of 20 per cent., figured in this particular test, I am satisfied that this condenser receives a considerable proportion of the discharge of the engines, not in the form of steam, as is usually assumed, but in the form of entrained water. It follows that the common recommendation that the condenser should be set as near as may be to the engine which it serves, in order that the full working value of the vacuum may be obtained, should be revised to stand something like this. The passage of steam from the engine to the condenser should be accomplished with a minimum loss of pressure—that is to say, with a minimum friction. Pipes leading from an engine to a distant condenser should be recognized as cooling surface and given every opportunity to radiate heat.

In our discussion last year Prof. M. E. Cooley pointed out that the pressure is a surface condenser is the sum of the pressures of all the vapors contained therein, and that the difference between the observed pressure and the steam pressure corresponding to the temperature is an evidence and a measure of the non-condensible vapor, presumably air, which is mixed with the steam. My observation is that this difference may be as much as 2 pounds absolute pressure—that is to say, that the temperature of the vapor in the condenser may be about 126 degrees, corresponding to an absolute pressure of 2 pounds, while the observed vacuum is equivalent to an absolute pressure of 4 pounds. The vapor pressures in the con-

denser, then, are 2 pounds steam pressure and 2 pounds air pressure; total, 4 pounds. The presence of this air means, of course, a 2 pounds reduction of the mean effective pressure in the low-pressure cylinder of the engine. Another common evidence of the presence of air along with steam is that a heater in which the pressure is maintained at a point above atmospheric pressure, so that no air can enter from the outside, but which is not provided with

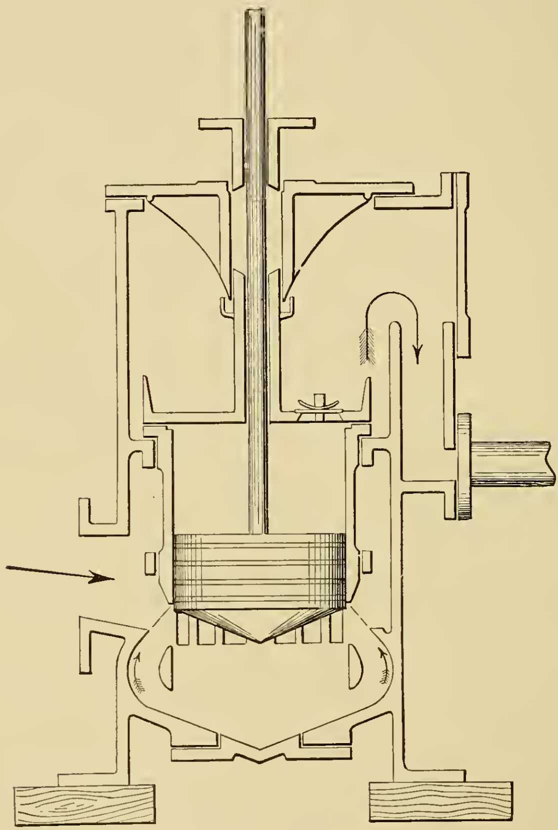


Fig. 2. Edwards Pump at Mid Stroke.

a thorough circulation of steam, nevertheless becomes air-bound. This air or other gas unquestionably enters the steam system dissolved in or entrained with the feed water. This is so well known in live steam purifier practice that provision is always made for the circulation of steam through the purifier, either by means of a pipe leading back to the steam main at a point where the pressure is lower, or by taking from the top of the purifier the steam necessary to drive the feed pumps or some other auxiliary. The air or non-

condensible vapor passes to the top of the purifier and is worked through the cylinders of a non-condensing engine along with the steam quite satisfactorily. It is only when an attempt is made to condense it that it proves troublesome. In a condensing plant, therefore, when live steam purifiers are used, it is desirable that the purifier circulation be obtained by piping to some non-condensing auxiliary which will discharge the non-condensible vapors outside of the condensing system.

In feed-water heaters there is also a choice between closed and open heaters. When a heater is interpolated in the main steam pipe between the engine and the condenser, of course, it must be closed; but the heater which receives the steam from the auxiliaries should be an open heater with a well-arranged vent system. Up to the point where the water is raised to boiling temperature the auxiliaries may be profitably run non-condensing; the obvious profit being the absorption of the heat of the auxiliary exhaust steam by the feed water; and the less apparent profit being the release from the feed water of all non-condensible vapor which can be driven off by the application of heat up to the temperature obtained in the heater.

When feed water is taken from the hot well or from the circulating system it should be taken at a point where the entrainment of air is a minimum. It is frequently taken from a surge tank in which the water is much aerated by splashing. If this aerated water goes to a vented open heater, in which it has an opportunity to stand after being heated, this air will be got rid of. If, however, it is pumped directly through a closed heater to the boilers, the aeration will not be got rid of and will inevitably reduce the vacuum in the condenser.

Those of you familiar with my own practice will know that I have erred within the past few years in every one of the ways indicated. But these meetings of ours are valuable, largely because we tell the things we *did not* know as well as those we now do know. That is why I am confessing my errors.

The air that gets past the heater and purifier and goes through the engines has finally to be removed from the condenser. When a contracted throat condenser, such as the Bulkley or Worthington cone, is used it is assumed that the air will be entrained by the falling injection water and swept through the throat and down the tail pipe. With the Weiss countercurrent condenser, in which the top chamber is essentially a spray chamber and there is no contraction of the discharge pipe, a dry vacuum pump is always made a part of the system. The first instance in my knowledge of the dry vacuum

pump being used with a steam engine condenser was in a Worthington plant, but I think we may credit the Weiss people with educating designers into the present common practice of making that kind of pump part of the equipment of every large barometric condenser. Its addition to such a condenser makes the operation much more convenient and reliable. I expect to see this custom extended to all large injector condenser equipments. In surface condenser practice, however, the tendency, as I noted last year, is toward the adoption of the vertical, single-acting type of pump which, when properly designed, disposes of the air accumulating in the surface condenser in a very satisfactory manner.

The new air pump, which we expected to install last year, is of the vertical type and known as the Edwards pump. It is not new in British practice. It is, in fact, being rapidly recognized as the standard on that side of the water. I have known of it for over two years, and when I learned that the Wheeler Condenser Company had arranged to manufacture an Edwards pump on this side of the water, I lost no time in placing an order. The accompanying drawing illustrates the action of the pump. You notice that it is single-acting. Usually there are two or three pump cylinders driven from cranks on the same shaft, so that the pumping is continuous; but each of these cylinders is an independent pump. The piston is flat on the top and conical on the bottom. The bottom of the pump cylinder, also, is coned to receive the piston on the downward stroke.

The pump being crank-driven, clearances can be made exceedingly small. Minimum clearance on top of the piston is of great importance. Consider the action of the pump if it is handling only air. On the down stroke it receives its charge through the ports in the sides of the cylinder which the piston uncovers as it reaches the bottom of its stroke. On the up-stroke the air above the piston, which was received at the pressure existing in the condenser, is compressed until its pressure is higher than that of the atmosphere to an amount sufficient to lift the valves. If there is no clearance, the entire charge of compressed air is expelled. If there is any clearance, that clearance remains filled with air at atmospheric pressure and its contents expands again as the pump makes the return stroke.

Consider, further, the effect of clearance when the discharge is partly water. In this particular pump the water remains below the air, and if there is enough water to fill the clearance space there will be no air left in the pump to expand during the return stroke. In many pumps, however, the interior arrangements are such that

there are pockets which remain filled with air. The pump must discharge not only against atmospheric pressure, but against the head of water lying on top of the valves. In the case of the steamer "Tashmoo," recently described to us by Mr. A. G. Mattsson, this back pressure is that due to a column of water of several feet, which is used to supply the trimming tanks. In such a case any air pocketed is compressed considerably above atmospheric pressure,

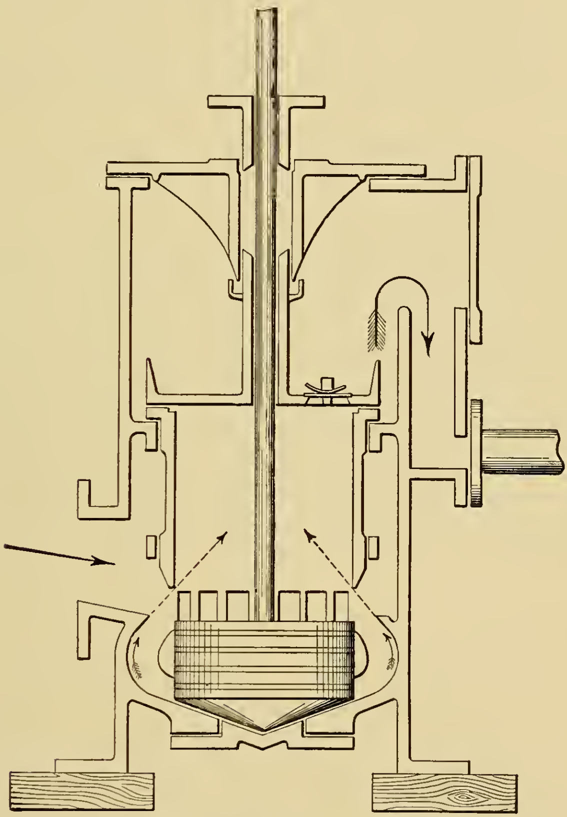


Fig. 3. Edwards Pump at Bottom of Stroke.

and expands afterward with increased detriment to the vacuum. In the Edwards pump a very small amount of water is retained on top of the valves, the dam shown on the drawing fixing the height at about 4 inches of water. Moreover, as it is a crank-driven pump, the dwell of the piston at the end of the stroke allows the valves to seat themselves before the return stroke is started and there is no back flow of water.

The action of the piston at the bottom of the stroke deserves special attention. You will notice that water and air entering the pump together are allowed at once to separate. The water gravitates into the conical bottom, while the air ascends into the annular chamber from which the ports open into the cylinder. When the piston comes down it strikes the water sharply, splashing it outward and upward. The form of the annular chamber is such that the water is thrown back into the cylinder through the ports and well up ahead of the piston. The air passes into the cylinder before the water, and as soon as the ports open; because the downward motion has produced a very good vacuum above the piston. The water is splashed and driven around after the air and is caught by the piston on the return stroke and carried upward on top of the piston and below the air. The air is discharged first and the clearance retains water only.

The distinguishing peculiarities of this pump are the absence of foot valves, and the manner in which the water is driven by impact into the pump chamber. There being no foot valves, the pump chamber is in perfectly free communication with the condenser at the proper moment, and the entire difference of pressure between the pump and the condenser acts to deliver water and vapor to the pump, none of it being required to raise intervening valves. In these respects it is superior to other good vertical pumps, while it retains the general good qualities of the vertical single-acting type; and, therefore, I believe is the best air pump on the market to-day.

# BREAKWATERS AND PLANS FOR BREAKWATER EXTENSION AT AGATE BAY, TWO HARBORS, MINN.

By S. M. White, Member of Engineers' Club of Minneapolis.

[Read before the Club, November 18, 1901.*]

A breakwater is a structure built for the purpose of breaking the force of the waves entering a harbor or anchorage. Breakwaters are usually built to protect the mouth of a natural harbor, but also for the making of an entirely artificial harbor or anchorage.

## EXAMPLES IN EARLY HISTORY.

Breakwaters, for the purpose of protecting harbors, are of very ancient origin. The harbor of Alexandria was protected by a stone mole called, from its length, the Heptastadium, or seven-furlong mole, which joined the island of Pharos and the mainland. It was probably commenced soon after the founding of the city, 332 B. C. It was pierced by two passages, which were spanned by bridges. It was probably built of rubble or riprap stone. An accumulation of alluvial deposits about it formed a broad neck of land, upon which the greater part of the present city of Alexandria is situated.

Herodotus states that Nebuchadnezzar built quays and breakwaters along the shores of the Persian Gulf. This would be between 604 and 562 B. C.

The harbor of Rhodes and the Piraeus of Athens were protected by moles, as were also those of many cities among the Romans. The Romans constructed the moles or breakwaters of many of their harbors upon a double row of arches, so arranged that the openings of one set were opposite the piers of the other. This construction thoroughly broke the force of the waves, while still permitting the passage of the current, thus greatly reducing the accumulation of deposits around the base of the structure and the consequent tendency toward filling up the harbor.

We are informed by Josephus that Herod, desiring to form a port on the coast of Syria, between Joppa and Dora, caused great stones, most of them 50 feet long by 10 feet wide and 9 feet deep, and some even larger, to be cast into the sea in 20 fathoms of water, with a view of forming a foundation for a mole or breakwater.

*Manuscript received January 18, 1902.—Secretary, Ass'n of Eng. Socs.

## RESISTANCE TO BE OVERCOME.

The resistance to be exerted by a breakwater is primarily that caused by the movement of water in waves.

The force exerted by waves is very great; and, as was said by Smeaton in connection with the construction of the Eddystone Lighthouse, "is a power of nature that is subject to no calculation."

Observation and experience furnish some data from which deductions may be made. Attempts have been made to measure the force of waves by means of the marine dynamometer, which consists essentially of a flat disk on which the waves impinge directly. These disks are from 6 to 9 inches in diameter, and are connected by rods with a strong spring inclosed in a cylinder, so that the stretching or drawing out of the spring can be determined, and from this the force of the waves can be measured or calculated. The force determined in this manner varied from 1.5 tons per square foot in the German Ocean to 3.5 tons in the more exposed parts of the Atlantic.

The work done by the waves in the destruction of breakwaters and lighthouses tends to confirm these experiments.

The most remarkable instances of wave power were observed at Wick Bay Breakwater. In 1872 a solid mass of masonry, 45 feet wide, 26 feet long and 21 feet high, weighing 1350 tons, was turned around upon its base and finally tilted off its foundation, and the following year at the same place a mass weighing about 2600 tons was moved in like manner.

The maximum height of waves which strike breakwaters in the North Atlantic is variously given as between 22 and 40 feet. Heights of waves as great as 60 to 108 feet above the hollow have been reported; but 50 feet is probably the maximum.

It has been found that the height of waves varies, in different localities, as the square root of the distance from the windward shore. From this the formula has been deduced $h = a\sqrt{d}$, in which $h$ = height of wave in feet, $d$ = distance or length of fetch in miles, and $a$ is a coefficient varying with the strength of the wind. $a = 1.5$ is used for heavy gales in deep water. In short fetches waves are raised higher than given by this formula. Long fetches, as the distance across the ocean, would be limited by the distance through which the gale was blowing.

This formula was deduced from observations upon the European coast of the Atlantic. In 1884 Mr. Wm. Peirson Judson, C. E., made some observations upon Lake Ontario at Oswego, N. Y. During a severe northwest gale, the waves, at a distance of 1000 feet outside the breakwater, attained a height of from 14

to 18 feet. The fetch from this direction is about 80 miles, and the formula would give a wave height of 13.5 feet.

I know of no accurate experiments having been made upon Lake Superior. A Government report upon Eagle Harbor, Mich., gives the maximum height of waves upon Lake Superior as 10 to 12 feet. I have observed waves which appeared to be 10 or 12 feet high with a southwest gale at Grand Marais, Minn. Here the fetch is about 64 miles. The formula gives a height of wave of 12 feet. At Two Harbors, Minn., the fetch from the southwest is about 30 miles, for which the formula gives a height of about 8 feet. This is somewhat higher than I have observed, but I was told of storms which I judge reached this height.

The greater number of severe storms at Two Harbors come from the northeast. The fetch from Isle Royal is about 120 miles, for which the formula would give a height of about 16 feet. I doubt whether the waves there ever go higher than 10 feet. The wind blows nearly parallel with the shore line, and the friction of the shore interferes with the free movement of the wave form.

It is generally stated that waves break when they reach a depth of water equal to their height, but they sometimes break in water of twice that depth.

"On the assumption that, at the instant of breaking, the vertical section of a wave at the surface is a common cycloid, and the height, h, of the wave is not greater than the depth of water in which it moves, theoretical considerations indicate that the maximum wave energy, in foot-pounds per linear foot of the wave crest, $= \frac{64 \pi d^3}{32} = 2 \pi d^3$; the weight of a cubic foot of sea water being taken at 64 pounds."* "For wave depths of 10 feet, this gives an energy of 6300 foot-pounds, and, for wave depths of 15 feet, about 21,000 foot-pounds. If the form of the wave, at the moment of breaking, is that of a prolate cycloid, as some authorities assert, its energy would be about 60 per cent. greater than that above stated. While such calculations are more curious than valuable, they nevertheless serve to convey some idea of the forces impressed upon breakwaters by wave action."†

### MANNER OF DESTRUCTION.

The destruction of a breakwater, or of any portion of one, is in many instances caused by the undermining of the foundation. The force of the waves is exerted to a considerable depth, especially

*Report Chief of Engineers, 1889, p. 1321.

†Paper by Louis Y. Schermerhorn, Mem. Am. Soc. C. E. in *Eng. News,* Aug. 25, 1898.

when given direction by a vertical faced wall. Hence, where a breakwater is founded upon a natural bottom of loose material or upon a mound of rubble stone, it should be protected by placing large stones or blocks of concrete on the exposed surface.

In some cases blocks of masonry have been torn out of the exposed face of a solid wall, and the disintegration of the breakwater started in this manner. In other cases, as in that of Wick, previously mentioned, a large portion of the superstructure may be moved and overturned.

The force exerted by waves is greatest when the waves strike at right angles to the line of the breakwater; hence, where possible, the line of the breakwater should be placed at an angle oblique to the direction of the prevailing heavy storms.

### RESISTANCE TO ICE.

In some localities breakwaters are subject to the action of ice. The force exerted by ice is greatest in the mouth of a river, where large fields of ice break loose and are given quite a high velocity by the current. At Delaware Breakwater, near the mouth of Delaware Bay, the ice fields come so that they would strike against the inside of the main breakwater. To protect the shipping, which might be seeking shelter from ocean storms, a secondary breakwater had to be built as a barrier against ice.

The pressure exerted by ice cannot be greater than its resistance to crushing.

For computing the necessary strength of the Delaware ice barrier, the formula was deduced: $u = \frac{1}{2} \frac{W}{g} V^2$. The greatest distance that a squeeze can be transmitted through ice is 1200 feet, as the ice crushes and the residual force is exerted in breaking it up. 1200 can then be used as the modulus of cohesion of ice under compression. Then, with b representing the breadth of a field of ice, d the depth, and the weight per cubic foot of ice being taken $= 57.4$ pounds, $W = (1200 \times b \times d)\ 57.4$. $g = 32.2$. Substituting in the formula the greatest possible effect of a field of ice $= u = \frac{(1200 \times bd)\ 57.4}{64.4} V$, the velocity V being that which the field of ice has acquired at the moment of impact.

Ice would not hold together with a high velocity, else in some cases it might obtain such a momentum as to be almost irresistible.

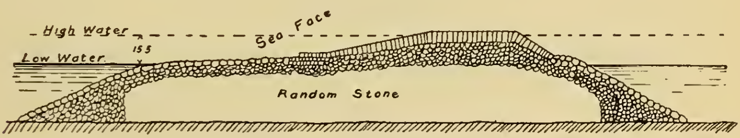
Upon Delaware Bay and in similar localities ice probably attains the velocity of one mile per hour and remains intact. Upon Lake Superior, before attaining that velocity, it would be broken up so as not to act as a solid mass; but, for the sake of seeing what

effect it might have, we will calculate with reference to the breakwater designed for Agate Bay. Assume a wide expanse of ice 1.5 feet thick, with a solid breadth of 600 feet, to strike against 410 linear feet of 24 x $24\frac{1}{2}$-foot timber crib breakwater. Then b = 600 feet, d = 1.5 feet, and, at one mile per hour, V = 1.47 feet per second, which, supplied in the formula, gives u = $\frac{1200 \times 600 \times 1.5 \times 57.4 \times 2.16}{64.4}$ = 2,080,000 foot-pounds of energy = W′S, W being the weight of the obstruction and S = the distance through which it is moved.

In this case W′ = about 13,200,000 pounds, which gives S = $1\frac{7}{8}$ inches. The breakwater might possibly stand a very few blows of that kind, but not many.

## MODERN METHODS OF CONSTRUCTION, WITH EXAMPLES IN FOREIGN COUNTRIES.

There are two general forms of construction, one with long sloping faces, the other with vertical or nearly vertical face. Then there is a form which is a combination of these two.




*Section of Breakwater at Plymouth, England.*

FIG. 1.

The long sloping-faced form is built of riprap or loose rubble or random stone, sometimes called "pierre purdue." It may have a core of gravel, sand or earth if at such a depth as not to be washed away either during or after construction.

The long sloping-faced form is called the "primitive form" in a recent article by an English engineer, and is very little used in recent construction in Europe and Asia.

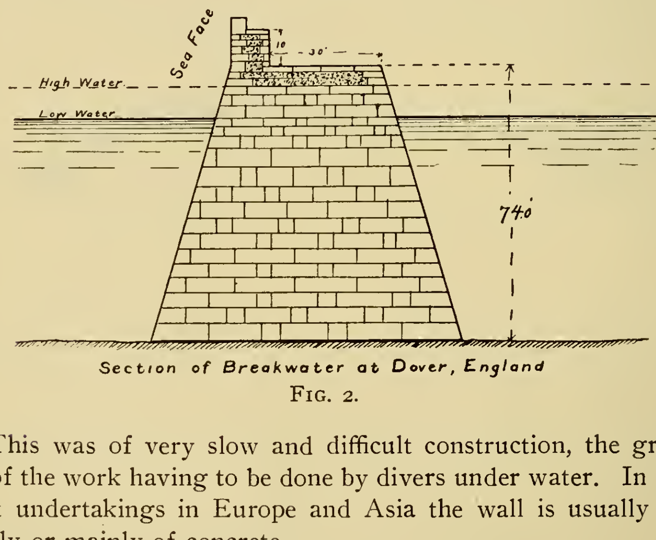
A very good example of this form is found in the breakwater at Plymouth, England. It was commenced in 1812 and completed in 1841, and hence is one of the oldest of modern construction. It is situated upon the inner one of three natural reefs of rock, which lie outside the harbor, and closes what was once a natural passage, leaving open passages to the east and west. The main body is placed perpendicularly to the south-southeast, and is 3000 feet long. Wings at each end form angles of 135 degrees, and are each 1050 feet in length. It protects a surface of 1120 acres.

A sectional view is shown in Fig. 1.

The breakwater is built entirely of riprap, except that the greater part above low water is revetted with masonry laid in Roman cement. 4,105,900 tons of stone were used in its construction, and cost $7,500,000. The slopes, which were largely governed by the action of the waves, are about as here shown.

This form of breakwater allows the water to roll over it, but the wave is so completely broken as to disturb the tranquillity of the harbor but very little.

Vertical-faced breakwaters cause the waves to be reflected back seawards. They require a very solid superstructure and foundation carried to at least twice the depth of the waves below low water, to prevent being undermined. Or the base may be protected by large blocks of stone or concrete in the form of riprap. They are built of solid stone masonry or concrete. The breakwater at Dover, England, a section of which is shown in Fig. 2, is a good example of solid ashlar masonry.




Section of Breakwater at Dover, England

FIG. 2.

This was of very slow and difficult construction, the greater part of the work having to be done by divers under water. In more recent undertakings in Europe and Asia the wall is usually built entirely or mainly of concrete.

One method of concrete construction is by building the underwater portion by depositing the concrete in sacks. The sacks prevent the concrete from disintegrating before it sets, and, when it is set, it conforms in shape to its foundation.

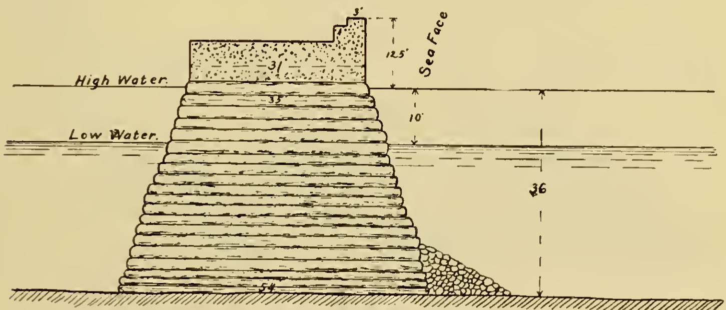
The breakwater for the harbor of La Guayra, Venezuela, was built in this manner. A section is shown in Fig. 3.

The sacks in the lower tiers were 48 feet long, but, when deposited, they stretched to 54 feet, and other lengths stretched in the same manner. Many of the sack blocks weighed 160 tons. The

blocks extending to water surface weighed 70 tons. The lower blocks were deposited from hopper barges, the upper ones from large tippers run out on six lines of rails. Upon the top of the substructure thus built concrete in mass was built in sections of 40 feet length, each section requiring $1\frac{3}{4}$ to 2 days to complete.

In the greater number of breakwaters situated in deep water the foundation is of loose rubble or riprap stone, and has a vertical-faced superstructure. The base of the solid superstructure varies, in different designs, between high-water level and 44 feet below low water.

A design which has met with considerable favor, and has been used in a number of places in Europe and Asia, has massive blocks of concrete sloping in the direction of length of the breakwater, these so placed that each section of blocks may settle independently; but the blocks in the sections are well tied together. The




Section of Breakwater at La Guayra, Venezuela.

FIG. 3.

top of the concrete block structure varies between low-water level and several feet above high water, and in several cases is topped with concrete in mass after settlement has ceased. A good example is the breakwater at Colombo, Ceylon, Fig. 4.

At this place a wall 24 feet wide, but otherwise of the same design, was moved 15 inches at the outer end by a heavy storm.

The most renowned example of the composite type of breakwater is that at Cherbourg, France, Fig. 5. It represents that form of the composite in which the riprap embankment comes above low water. It was commenced in 1784 and finished in 1853. It is about 3 miles long, and cost about $12,500,000.

The wall starts at low water, with a bed of hydraulic concrete 5 feet thick, and upon this was erected a solid wall of coursed ashlar masonry faced with granite. The top of the sea slope is covered with large loose blocks, and at the extremities of the wings

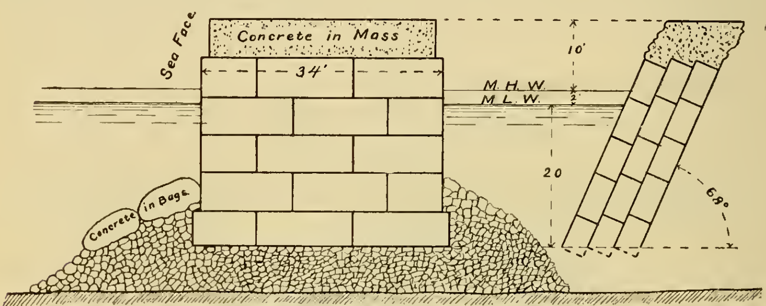
it is further protected by immense blocks of concrete weighing about 40 tons each, forming a rubble set in hydraulic cement.

A number of ingenious designs in concrete construction, especially adapted to the places for which they are designed, have been built in Europe in late years.

SEACOAST PRACTICE IN THE UNITED STATES.

Upon the seacoast of the United States the universal practice is to build breakwaters of rip-rap or random stone. This is principally due to the fact that near their locations good stone is cheaply obtained, making this the most economical method of construction.

The first breakwater built in the United States, and the only one for some time, was the Delaware Breakwater at Lewes, Del.,



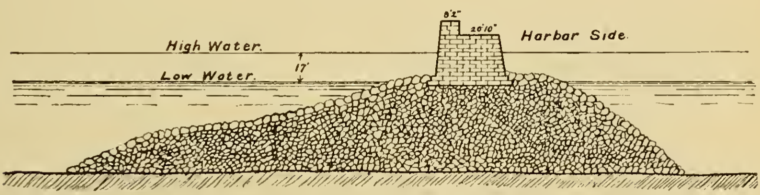

Concrete Block Breakwater at Columbo, Ceylon

FIG. 4.

just inside the mouth of Delaware Bay. It was built for a harbor of refuge for vessels passing along the coast. It was started in 1828. Although it has an anchorage area of 420 acres between 3 and 6 fathoms deep, its capacity has been fully utilized during storms, and an additional breakwater is now being built 2.5 miles north, with an area of 562 acres, having a minimum depth of 30 feet, and 237 acres additional between 30 and 24 feet deep. The original Delaware Breakwater consisted of the breakwater proper, 2558 feet long, and an ice breaker 1359 feet long, to protect the harbor thus formed from ice brought down by the Delaware River. Between these was a passage 1390 feet wide. This gap was closed several years ago, to give additional anchorage room and security. The total cost of these 5307 feet of breakwater was about $3,000,000. An average cross-section of Old Delaware Breakwater is shown in Fig. 6.

The embankment was made of less width than those of similar construction in Europe, the sea face slope in several cases of

European construction being as flat as 1 vertical to 7 or 8 horizontal between high-water line, and 10 or 12 feet below low water, or on part of this distance. In some cases level benches divided the slope, making a foreshore of extra width for the waves to break upon. The slopes in Delaware Breakwater are very nearly those given by the action of the waves. The waves are higher where most of the European breakwaters are situated, but the difference in slope seems greater than should be required. The slope is also determined by the size of stones used. The ordinary sizes of rock used, ranging usually from 40 to 2000 pounds in weight, will stand at a slope of 1 vertical to 1.5 horizontal up to about 12 feet below low-water line, with waves as on the American coast. This depth marks what is called the plane of rest, or limit of energetic wave action. The depth of the plane of rest varies, of course, with the energy of the waves and with the size and character of stone used. Above the plane of rest much flatter slopes must be used. By




Section of Breakwater at Cherbourg, France.
FIG. 5.

protecting the surface of the slope with the largest stone that can be economically handled, the steepness of the slopes needed may be increased. By using surface stones above 3 tons in weight, the average slope between high-water level and the plane of rest is increased to 1 to 3 in American practice.

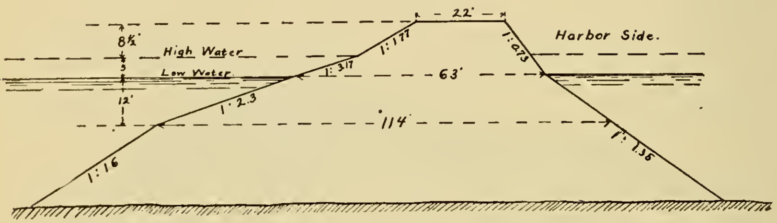
The superstructure, or part above high-water level, in the most recent types of American random stone breakwaters, consists of rough, strong walls upon the sea and harbor faces of the work, built of larger stone systematically placed, so as to secure a strong bond; the space between these walls being filled with stone varying in size, so as to form a compact mass. The placing of these large stones requires the use of very powerful derricks. The sea slopes of superstructures built in this manner vary between 1 to 0.7 and 1 to 1. Otherwise the cross-section of the recent designs of American coast breakwaters is in most cases nearly the same as in the Old Delaware Breakwater. Old Delaware Breakwater was under construction from 1828 to 1840, and from 1866 to 1869, and the gap was closed during the years 1883 to 1899. Separate con-

tracts were let under each appropriation by Congress. The average cost per ton of rock for the first two periods was $2.50, for the last $2.30.

The more recent projects have been let by continuous contract, or by one contract to cover the entire construction, but paid by several appropriations, the number varying with the time required. This results in a great saving, as the contractor is warranted in investing in a working plant adequate to handle the work most economically. The New Delaware Breakwater was thus let at $1.18½ per ton, a saving of about 50 per cent. over former prices.

### CONDITIONS ON THE GREAT LAKES.

The conditions on the Great Lakes differ from those on the ocean, mainly in that the waves do not attain so great a size and that the water is fresh instead of salt.




*Average Section of Old Delaware Breakwater*
FIG. 6.

The waves being smaller, a less massive construction of breakwater is required; but the principal difference between the usual manner of construction upon the Great Lakes and that upon the ocean is due to the fact that timber may be used in fresh water for permanent work, while in salt water it cannot, owing to its being destroyed by marine worms. Timber when kept constantly under fresh water will last for an indefinite time, and seems not to deteriorate or lose any of its strength. Adding to this the fact that the Great Lakes were surrounded by immense forests of pine, hemlock, etc., making timber very cheap, we have conditions which make timber cribs, filled with rock, the most economical method of stable construction of breakwaters.

The rock is held in the form of a solid wall by the crib at a considerably less expense than would be required for a solid wall constructed in any other manner.

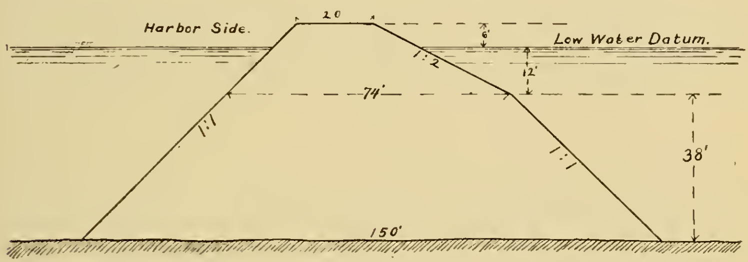
A random stone breakwater would require so much more stone as to make it much more expensive.

COMPARISON OF COST OF DIFFERENT METHODS OF CONSTRUCTION.

We will now make a comparison of cost of some different methods of construction which might be used for the Agate Bay Breakwaters.

We will figure for a depth of 50 feet below low-water datum, as this is nearly the average depth of the Agate Bay Breakwater extensions.

First. A random stone breakwater of the form recently built at Point Judith, R. I., a section of which is shown in Fig. 7.



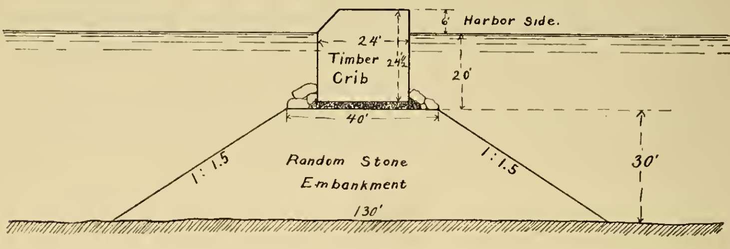

Section of Point Judith, R. I., Breakwater, except 4' lower for Lake Superior

FIG. 7.

This is probably as economical a section as would retain its stability at this location, and would require that, below 12 feet below datum, the plane of rest, the slopes be covered with stones weighing from 1 to 5 tons, and that, above the plane of rest, the slopes and top be covered with stones weighing from 3 to 10 tons, and the upper 10 feet be systematically laid so as to secure a strong bond. This section contains 5102 cubic feet per running foot of breakwater. 5102 cubic feet equal 39.86 cords of rock. 39.86 cords, at $6.50 per cord, equals $259.09 per running or linear foot of breakwater.

Second. A breakwater with random stone foundation, concrete blocks from — 16 to + 1 and capped with concrete in mass to + 6. Concrete structure 20 feet wide, built as at Colombo, Ceylon (Fig. 4). Width of random stone embankment at — 16 to be 40 feet. Slopes 1 to 1.5, extending up to the side of concrete. The riprap at the sides of the concrete to be of stones exceeding 3 tons in weight. Cross-section area of rock embankment and riprap equals 3160.7 square feet. 3160.7 cubic feet equal 24.77 cords of rock per linear foot. 24.77 cords, at $6, equal $148.62. 452 cubic feet equal 16.74 cubic yards of concrete per linear foot. 16.74 cubic yards, at $6.50, equals $108.81. Total cost per linear foot, $257.43.

Third. The form of breakwater adopted was composed of timber cribs and superstructure upon a random stone or riprap embankment. Cross-section, for 50-foot depth of water. (Fig. 8.)




Section of Breakwater built at Two Harbors, Minn.

Fig. 8.

Stone embankment to 20 feet below datum measures 2550 cubic feet = 19.92 cords, per linear foot. 19.92 cords, at $6, cost $119.52 per linear foot. Crib and superstructure, all above elevation — 20, $75.30 per linear foot. Total, $194.82 per linear foot.

This is $63.61, or nearly 33 per cent. less than the probable cost by other methods. This would amount to $25,440 for 400 feet. Without stopping to calculate for the various depths, either of the first two methods would probably cost about $100,000 more for the total 1960 linear feet than the $240,000, which the third method will cost.

#### REBUILDING OF SUPERSTRUCTURE OF TIMBER CRIBS.

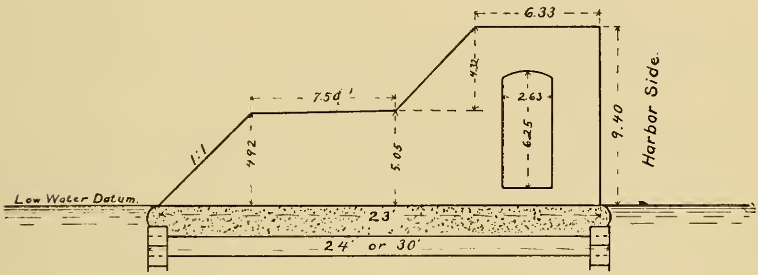
The superstructure, or that part of the breakwater above low-water datum, will, in about 20 years, have its timber work rotted so as to impair the strength. This could be replaced for probably about the original cost of the superstructure, $20 per linear foot; but if a permanent structure is desired, it would be better to rebuild the superstructure of concrete.

In a case of this kind it is better not to build the concrete superstructure at first, as the structure is subject to settlement. The timber superstructure being more elastic than the concrete, it is not seriously injured by a considerable amount of settlement; while the concrete would be. Before the superstructure needs replacing, the cribs will most likely have reached an unyielding position. If not, they can in nearly all cases be made to do so by more riprapping. A very good design for concrete superstructure is that which has been placed upon part of the timber crib breakwater at Marquette Harbor, Lake Superior, and will be placed upon the

remainder as soon as possible after the money has been appropriated by Congress. A cross-section of it is as shown in Fig. 9.

The timber work is removed to one foot or a little more below low-water datum, and the stone filling made compact over the top. Upon this Portland cement concrete is laid up to datum, it being held in place by burlap before setting. The part above datum is built of natural cement concrete in lengths of 10 feet.

The cost per linear foot of blocks was $20.48; of blocks and footing, $30.10; with all accessory work, which includes the removing of timber and stone, $41.88 per linear foot. To finish in this way there would be a saving of only 12 to 15 per cent., in addition to the interest on the money, over what a permanent structure would cost.




*Concrete Superstructure on Timber Crib at Marquette, Mich.*

FIG. 9.

To obtain the figures given for a permanent structure, however, it would undoubtedly have to be let in one or a very few large contracts, which would require more money at once than Congress has heretofore been willing to appropriate for a harbor of this class.

### GENERAL PRINCIPLES OF TIMBER CRIB CONSTRUCTION.

The first great crib breakwater was built at Buffalo, N. Y. Before deciding on the design to be followed, the Advisory Board of United States Engineers of 1853, formulated some general principles to be followed in the construction of timber crib breakwaters. These are regarded practically as axioms.

They are as follows:

"The cross-section of the foundation cribs should fill certain practicable condition. They should be:

"First. Of such figures as to throw the common center of gravity of the foundation and superstructure low down.

"Second. Of such lines for its sides as will enable us with simplicity and effectually to tie the superstructure down to the foundation, so as to make the under water and above water parts inseparable by the action of a force against the mass.

"Third. Such that the crib can be easily floated, in a position of stable equilibrium, from the place where it is framed, out of the harbor, and sunk where it is to stand. This implies symmetry of parts on both sides of the vertical line passing through the common center of gravity.

"Fourth. The walls of the crib constituting the foundation should rise in such a manner, in regard to angle with the horizon, that the weight of the walls of the superstructure may be as much as possible transmitted directly to the walls of the crib, and not bear upon its cross-ties at points inside its walls. Again, the walls should rise in such manner that the rubble stone filling, which must be thrown or dropped in, will assume a position bearing well against the sides of the walls.

"Fifth. The width of the base of the foundation should not be unnecessarily large, for it would require splicing of ties and bottom timbers to make them long enough, which would be very expensive and produce unnecessary cost of construction."

These conditions are best met when the crib and superstructure have a square (or very nearly square) cross-section. This being the case, the timber crib work can be economically built only to a limited depth.

ECONOMIC PROPORTIONS OF CRIB AND RIPRAP EMBANKMENT.

The usual plan in constructing this style of breakwater in deep water is to have the lower part of foundation composed of riprap or random stone embankment. To determine the proper relative proportions, considering the cost of the work, Mr. J. H. Darling, First Assistant Engineer at the Duluth office of United States Engineers, deduced the following formula. See Fig. 10.

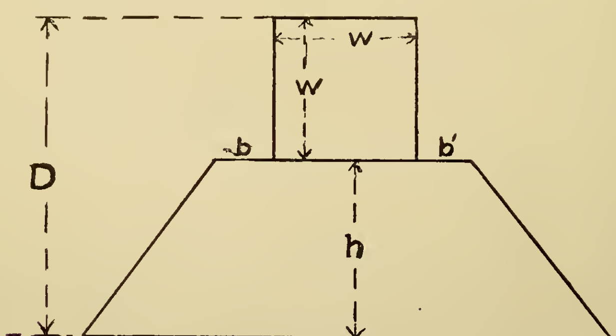



Fig. 10.

D = Depth of breakwater.

h = Height of embankment.

W = Width and depth of timber pier.

$B''$ = Sum of berms b and b'.

S = Ratio of slope, base to vertical.

R = Ratio of cost of timber pier to embankment for equal volumes.

U = Cost of linear foot of breakwater in terms of a cubic foot of embankment.

Then $U = R\, W^2 + h\,(W + B'' + S\,h)$

As $h = D - w$

$U = R\, W^2 + (D - W)\,(W + B'' + S\,D - S\,W)$

For minimum values of U

$$\frac{dU}{dW} = 2\,(R + s - 1)\,W + D - S\,D - B'' - S\,D = O$$

$$\text{Whence } W = \frac{B'' + (2\,S - 1)\,D}{2\,(R + S - 1)}$$

To apply this formula, we will compute the ratio of cost from that of a 24 x 24½ x 50-foot crib, which contains 29,400 cubic feet in volume.

Prices intended to represent probable cost of material in place, with 15 per cent. for contractor's profit and 10 per cent. for risk:

| | |
|---|---|
| Pine timber, 76,720 feet B. M., at $30 | $2,302.00 |
| Iron fastenings, 5257 pounds, at $3.50 | 180.00 |
| Stone ballast, 162 cords, at $7 | 1,134.00 |
| Cost of 50 linear feet, or 29,400 cubic feet | $3,616.00 |
| Cost per cubic foot of timber pier | $0.123 |
| Cost per cubic foot of stone for embankment, at $6 per cord | 0.047 |

Ratio of former to latter: R = 2.6.

TABLE FROM FORMULA WITH S = $^3/_2$ AND B″ = 16 FEET.

| Depth of Water. Feet. | D = Depth of Entire Breakwater. Feet. | W = Economic Width of Timber Pier. Feet. |
|---|---|---|
| 10 | 16 | 7.7 |
| 20 | 26 | 11.0 |
| 30 | 36 | 14.2 |
| 40 | 46 | 17.4 |
| 50 | 56 | 20.7 |
| 60 | 66 | 23.9 |
| 70 | 76 | 27.1 |

The ratio of cost would vary somewhat with the different widths, but not enough to affect the results materially. For stability of structure, the widths are increased over those given by the calculations. In shallow water the least width used is generally 16 feet, with 24 feet as common practice in water from 20 to 50 feet deep.

## CONDITIONS EXISTING AT AGATE BAY.

We will now consider the conditions existing at Agate Bay, Two Harbors, Minn.

Agate Bay is the western one of two contiguous bays which give to the town the name of Two Harbors. As shown in Fig. 11, the harbor is very nearly a semicircle of 2000 feet radius, the direction of the opening being a little east of south. The general trend of the shore in its vicinity is northeast and southwest. The prevailing storms come from the northeast. It is protected from the direct force of these by the point between it and Burlington Bay, but the reverse swells from the northeasters come into the harbor with considerable force. A few hard storms each year come from the southwest. To these the harbor was almost fully exposed.

The line of 18 feet depth of water was only about 600 feet from the shore in the farthest place and the water is 60 feet or more deep in the center of the entrance, so there was plenty of water for the largest vessels. This bay was decided upon by the Duluth and Iron Range Railroad as their port for shipping iron ore, and in 1883-1884 the first ore dock was built. Now there are five ore docks, with a combined capacity of 162,040 tons, a merchandise dock, used largely in shipping lumber, and a coal dock.

In addition to its shipping interests Agate Bay is frequently used as a harbor of refuge by vessels going to or from the harbor of Duluth and Superior.

## HISTORY OF WORK PREVIOUSLY DONE.

The original project was to build 1000 linear feet of breakwater from the east side and 900 feet on the west side, on a direct line toward each other, with an opening of 1340 feet between them, these to inclose an area of 109 acres. The estimated cost was $244,208. This project was approved January 4, 1887.

Four hundred linear feet of East breakwater was built in 1887, 16 and 20 feet wide; 150 feet in 1889, 20 and 24 feet wide; 200 feet in 1891, 24 feet wide. This first 750 linear feet cost $61,384.59.

The West breakwater was built as follows: 200 linear feet in 1893; 400 feet of embankment in 1895 and 1896; 250 feet of cribs and superstructure in 1896; 410 feet of embankment in 1897, and 300 feet of cribs and superstructure in 1898. In October, 1896, a large vessel went adrift in a heavy storm, and struck the uncompleted end of the West breakwater, carrying away and destroying 100 linear feet of cribs. One of the 50-foot cribs was not broken to pieces; but was pushed over the side of the embankment into the

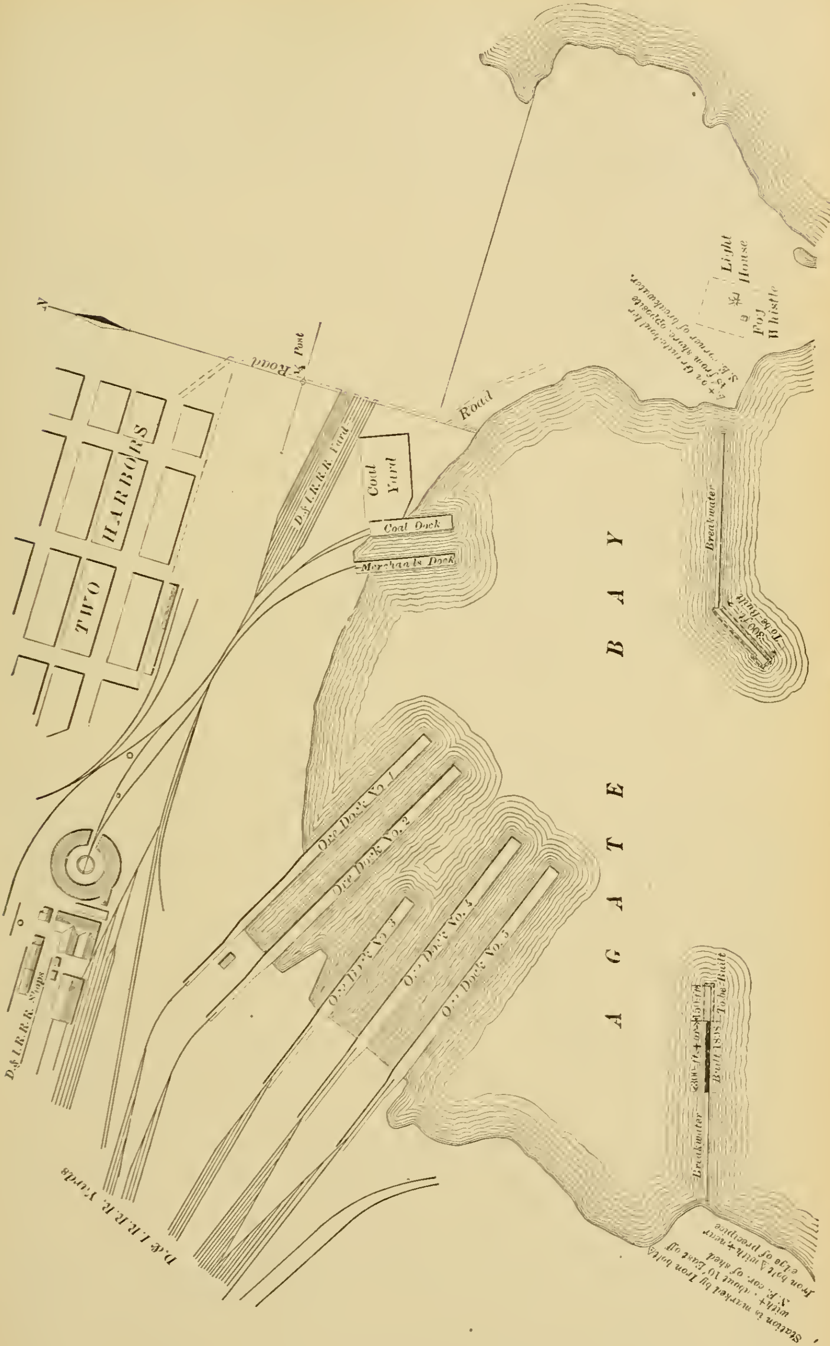

TWO HARBORS
AGATE BAY
Coal Yard
Coal Dock
Merchants Dock
D. & I. R. R. Yard
Road
Road
Breakwater
Breakwater
Light House
Fog Whistle
To be Built
Built 1898
D. & I. R. R. Shops
D. & I. R. R. Yards

FIG. 11.

harbor. It still lies there, with its top corner about 10 feet below the surface of the water. The end of the adjoining crib, which remained on the bank, was moved into the harbor about 8 feet, necessitating a jog of about 6 feet in the alignment and some special fitting, in order to connect solidly.

The appropriations by Congress for the work were made as follows:

| | |
|---|---|
| August 5, 1886 | $22,500 |
| August 11, 1888 | 15,000 |
| September 19, 1890 | 25,000 |
| July 13, 1892 | 30,000 |
| August 18, 1894 | 30,000 |
| June 3, 1896 | 50,000 |
| March 3, 1899 | 71,708 |
| Total | $244,208 |

The balance unexpended July 1, 1899, was $72,227.48. Of this amount about $27,000 was covered by contract for the riprap embankment to complete the East breakwater.

In 1897 $1150 was spent in repairing East breakwater. Further repairs are necessary to replace rotten deck plank and side wall of superstructure where broken by collision of a vessel.

### REQUIREMENTS FOR FINAL EXTENSIONS.

On March 23, 1899, the Chief of Engineers, United States Army, approved of building 300 linear feet at the end of East breakwater at an angle of 45 degrees toward the lake, instead of the final 250 feet in the straight line of the original project. This gives to the ore docks additional protection from northeasters. While it does not give to the harbor any additional protection from southwestern storms, the flare in that direction is not sufficient to cause additional disturbance. The change also affords additional room for handling the large vessels going to and leaving the ore docks.

Had the increase in the amount of iron ore shipped from this port and in the size of the vessels carrying it been foreseen at the time the breakwaters were first planned, undoubtedly they would have been built farther out into the lake.

At the time of the approval of the change of plans, March 23, 1899, there remained to be built, to complete the project, 150 linear feet of cribs and superstructure on the West breakwater, and 313 linear feet of riprap embankment and 310 linear feet of cribs and superstructure for the East breakwater.

### APPLICATION OF THE GENERAL PRINCIPLES AND THEORY OF PROPORTIONS.

Comparing the accompanying plan with the general principles laid down by the Engineer Board of 1853, the form of breakwater is seen to fulfill the conditions therein expressed. The foundation crib is rectangular, of greater width than depth and symmetrical, which throws the center of gravity well down and allows the crib to be towed without danger of overturning. Cribs of similar plan have been towed 125 miles upon Lake Superior. In the latest design the outer wall of superstructure has a slope of 1 to 1, so its weight and the forces exerted upon it are not entirely carried by the wall of the crib. The force is not exerted upon unsupported tie beams, however, for the tie beams are supported continuously, from a point under the top of the slope to the bottom of the crib. The condition that the walls should be of such form that the rubble stone would bear well against the sides was formulated with the idea of having no ballast floor, the pressure of the stone against the sides holding the crib down against its buoyancy as well as receiving external forces. In more recent practice, however, center pockets with floored bottoms are put in and the buoyancy is more quickly overcome.

In the table, worked out under the theory of economic proportions, the prices and other data used were taken so as to apply to this work. The extension of East breakwater lies in from 38 to 60 feet depth of water. From the table, the width for 40 feet is 17.4 feet, for 50 feet it is 20.7 feet, and for 60 feet it is 23.9 feet. These are all seen to be less than 24 feet, which was the width of the preceding portion of the structure. This width of 24 feet was found to be necessary for stability, as, during the cessation of work from 1889 to 1891, the 20 feet by 20 feet pier was moved 2 feet laterally at the end. Hence, 24 feet by 24 feet is the proper section for cribs and superstructure in this place. On the west side the conditions are about the same, so that 24 feet by 24 feet is the proper section here also.

At the end of East breakwater is placed a Government light, and being very close to the course usually taken by vessels in entering the harbor, it was desirable also to have the end more prominent; so it was decided to make the superstructure, over the end crib, 10 feet above low-water datum, or 4 feet higher than the rest, making a total height of crib and superstructure of 28.5 feet. This outer crib being very much exposed to the action of storms, the width was made a little greater than the height, or 30 feet.

### LENGTH OF CRIBS.

The proper cross-section having been determined, the length of cribs should be considered next. This should be such that the crib will have sufficient weight to withstand any concentrated shock which it is likely to receive; but at the same time the crib should not be too long to be readily handled. If very long, the crib might not come to a solid bearing throughout its entire length. The full weight of rock would then deform the structure or put very heavy strains on some of its parts.

The chief objection to a long crib, however, is that it takes so much rock to sink and fill it that there is great danger of a storm coming up and wrecking it before it can be made secure. The length which can be safely handled depends in a large measure upon the size of the outfit employed. A contract of the size of that called for by these extensions does not warrant the use of a very large outfit. Two good-sized scows (of not less than 200 tons capacity), and a tug to handle them, are all that could be expected where the rock was obtained not more than 4 or 5 miles away. A crib longer than 50 feet could hardly be made safe in one day with this outfit under ordinary conditions, and one day is as long as the weather can usually be depended upon to remain good. Hence, 50 feet was the length of crib decided upon.

Contractors with a quite complete outfit for this work sometimes prefer to build cribs of 100 feet length. Under the usual Government specifications the crib is at the contractor's risk until it is completely filled with rock, the ballast boxes planked over and the required riprap placed around the sides. Hence, if the contractor is seen to have a sufficient outfit, he is usually allowed the privilege of building cribs of 100 feet length where practicable.

### CALCULATIONS AS TO STRENGTH OF VARIOUS PARTS.

Having determined the proper dimensions of the crib as a whole, let us now consider the proper dimensions of its composite parts. In this case, where we have to continue, with a similar design, a project which has already been partly completed, all we need to do is to check the dimensions of some of the principal parts.

The most important part of the framed structure is the exterior wall. In the preceding construction, and in nearly universal practice, 12 x 12-inch white or Norway pine is used.

In the preceding plan these were supported against the side pressure, at intervals of 7 feet, by the tie beams. Hence, we will consider the strength of a 12 x 12-inch pine beam 7 feet long. Using Trautwine's formula for a beam supported at both ends,

$w = \frac{12.5\, bd^2}{l}$ (all in inches), we obtain 37,000 pounds as the safe quiescent load.

The timbers are held against the external pressure in a large measure by the contained rock, so the outward pressure of the rock is the principal stress. The depth of rock in the side pockets is 24 feet. The bottom 4 feet may be disregarded for side pressure, as it is counterbalanced by the side riprap. 5.5 feet by 7 feet by 20 feet = 770 cubic feet, or 6 cords. The average weight of a cord of the rock used here is 6 tons, or 12,000 pounds. Three-fourths of this rock is under water, and thus loses about one-third of its effectual weight. Deducting one-quarter, we have the effectual weight, 54,000 pounds. If this were a liquid, 54,000 pounds would be the side pressure, but for stone it is probably not over half this, or 27,000 pounds. This is well under the 37,000 pounds strength of timber beam.

The dovetailed end of the tie beam is subject to a shearing strain. The section subject to shear is 12 inches by 12 inches = 144 square inches. Using 300 pounds per square inch as the ultimate strength, the total resistance to shear is found to be 43,200 pounds. This is rather close to the probable greatest pressure of 27,000 pounds; but only the lower timbers have to stand this strain, and I think the tightening of the joints, by swelling under water, increases their resistance to shearing. I have never heard of one of these joints failing.

The drift bolts used in the preceding plan were of ⅞-inch round iron. The area is very nearly 0.6 square inch. At 40,000 pounds per square inch, the ultimate shearing strength of a bolt is 24,000 pounds. The least number used between ties and joining two timbers is two. If the greatest pressure of rock of 27,000 pounds were to act to separate two timbers, this strength of bolt would not be a safe one; but the pressure will act on several timbers combined.

The other sizes of timber and iron are of minor importance, and they have been determined largely by experience.

### REASON FOR BALLAST BOXES AND OPEN SIDE POCKETS.

As previously mentioned, the first cribs for construction of this kind were built without any bottom flooring. They then had to be sunk by putting a temporary floor over parts of the top and covering this with sufficient rock to sink the crib. After being sunk to the proper position in this way, the crib was filled inside, and it would have to be filled full before it would be secure against even a small storm. The object in having the bottom open was to have the rock filling bind itself as securely as possible into the earth

bottom or rock embankment underneath. The crib then simply acted to hold the rock in the shape of a wall. The placing of the rock on top required considerable care and time, and the space it occupied interfered considerably with the filling of the pockets. To overcome these objections in sinking and make the crib more secure in case of a storm arising before its filling and covering were completed, ballast floors were placed in the bottom of the middle pockets.

The open sides of pockets leave sufficient space for the rock to bind itself into the bottom or embankment beneath. To make a solid structure this is most needed at the sides to take the thrust of the waves as well as make it more stable of itself.

### METHOD OF SINKING.

When the crib is built with the intention of having it sunk entirely below (or at least to) the water surface, as required here, it should be sunk while at its mooring in the harbor until only about 2 feet of the walls are out of water. The embankment or bottom having been leveled to the proper height and the scows fully loaded with suitable rock, with more rock ready for loading, the crib is ready to be sunk. After this, as soon as a calm morning arrives, with indications that the weather will remain good, the crib is taken out and secured in place. Various methods of securing are used, according to locality and circumstances. After other cribs are in, as in this case, the inner end is secured to the preceding crib. Turnbuckles are best for pulling them tightly together. The inner end is held from moving laterally by means of projecting spurs engaging upright guide posts on the end of the preceding crib.

A very efficient means of holding the crib in place, and especially to the proper level, is with guide poles secured in the corners of the crib, so as to be let down upon the bottom and project far enough above the top to allow of efficient use of blocks and tackle. The weight of the crib is then placed upon these before it is sunk clear down and its level largely controlled by their use. It is best to do the last part of the sinking to grade by means of rock placed on top, so that during the first part of the operation it may be raised by moving the rock if necessary. The crib is held a little above the final grade, to allow for settlement in filling and also afterward under the action of storms.

As soon as the crib is at the proper line and grade, small stones, not over 6 inches on a side and preferably cobble stones, are thrown into the open pockets and around the sides of the wall, so that they will work under the walls and bottom timbers and give the crib a firm and even bearing all around.

When these small stones are about $2\frac{1}{2}$ feet above the bottom in all the open pockets, stones ranging in size up to 2 feet on a side are thrown into all the pockets as nearly equally as possible. The stones in the ballast boxes are large enough not to work out between the side timbers. When full, the ballast boxes are covered over with plank well spiked, and large riprap stones are placed around the sides as soon as possible. The crib is then deemed secure against any storm, and is accepted by the Government.

### BUILDING OF SUPERSTRUCTURE.

The crib is given at least two weeks in which to settle before the superstructure is started. The superstructure is made level on top. In case of undue settlement extra timber must be placed upon the crib. Generally the leveling is done by varying the thickness of the first timber of the superstructure. No timber under 2 inches thick must be used in leveling. In the superstructure, with 1 to 1 slope on the face, the vertical wall on the harbor side is leveled first and the bottom course of tie beams is leveled out from this.

The superstructure of West breakwater has a vertical face, while that for the extension of East breakwater has a 1 to 1 slope. West breakwater extension is made vertical because it is an extension, in the same line, of cribs and superstructure of the same design, and is only 150 feet long. The 1 to 1 slope is of recent design for timber crib superstructure, which, it is thought, receives less shock from heavy seas than does the vertical-faced type. The extension of East breakwater is at an angle of 45 degrees into the lake from the preceding portion, which brings it more nearly at right angles to the prevailing heavy storms. Hence, the safest design should be adopted. With heavy waves striking against the 1 to 1 slope, part of the force acts downward, with no tendency to overturn or move the crib; while with the vertical face all the force would act to overturn or move. On account of the change in direction the change in form does not mar the appearance of the structure. Waves roll over the sloping-faced form more easily than over the vertical-faced form; but this does not make the harbor any rougher, for the wave form does not go beyond the breakwater.

Further particulars as to the building of the cribs and superstructure are explained by the plans and specifications.

### BUILDING OF EMBANKMENT.

As the last contract did not include the building of any embankment, I have merely mentioned the building of embankment heretofore.

The embankment was built of trap rock and Duluth granite. The trap rock was obtained from the point between Agate and Burlington Bays, hence very close to the work. Most of the cribs were filled with this also; all in the last contract. The Duluth granite was obtained about 5 miles up the shore, where the quarry was more easy to work; the rock, when blasted out, rolling to the water's edge. At both places it was loaded onto scows by derricks, either on the scows or on the shore. This rock weighs from 175 to 180 pounds per cubic foot, or 6 to $6\frac{1}{2}$ tons to the measured cord.

The core of the embankment was made of any sized rock above 20 pounds weight. The slopes were covered with angular stones weighing not less than 2 tons.

## COMPLETION.

The construction of these extensions, in accordance with the plans herein described, was successfully completed November 1, 1901. This finished the projected improvement of the harbor by the Government.

ATERS AT AGATE BAY, MINN.

S FROM

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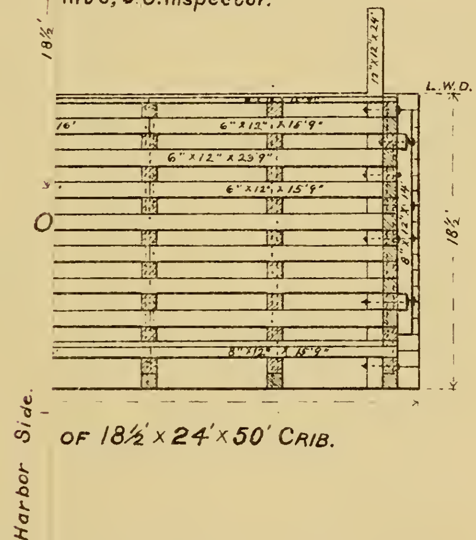
TER EXTENSIONS

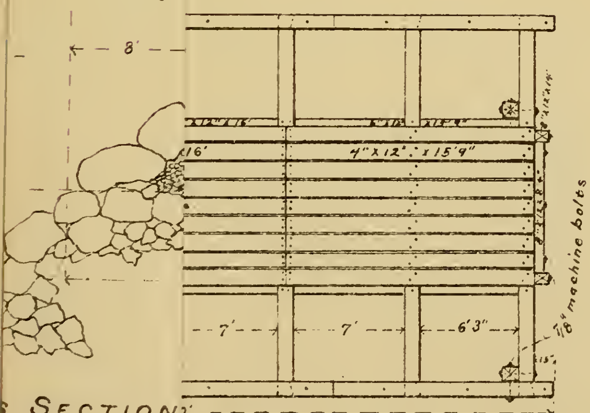
# AY, MINN.

S DATED DEC. 15, 1899.

'ection of Major
Engineers, U.S.
'hite, U.S. Inspector."




OF 18½' x 24' x 50' CRIB.




SECTION

' OF CRIB.

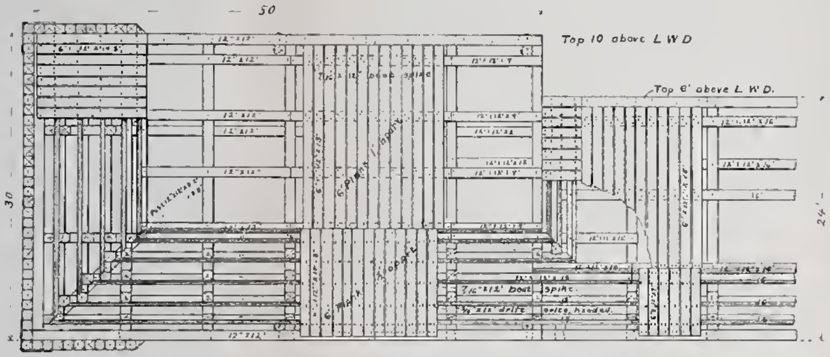
PRINCIPAL FEATURES OF EAST BREAKWATER EXTENSION.

ILLUSTRATIONS FROM

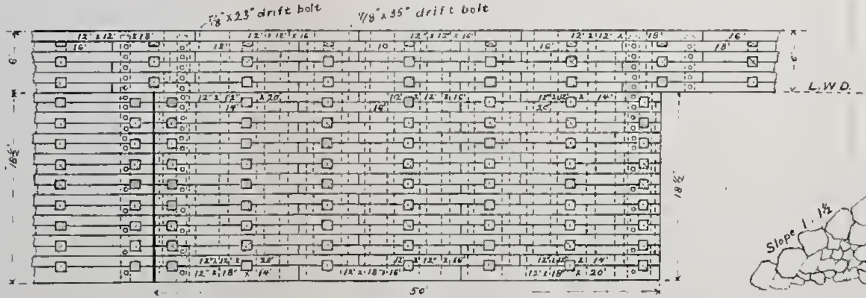
# "PLANS FOR BREAKWATER EXTENSIONS AT AGATE BAY, MINN.

TO ACCOMPANY SPECIFICATIONS DATED DEC. 15, 1899.

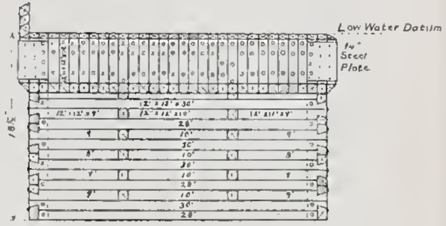
Designed under the direction of Major Clinton B. Sears, Corps of Engineers, U. S. Army, and drawn by S. M. White, U. S. Inspector."



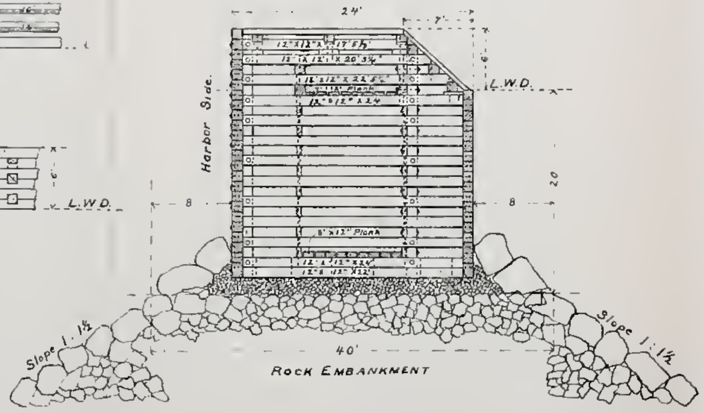

PLAN OF SUPERSTRUCTURE AT OUTER END



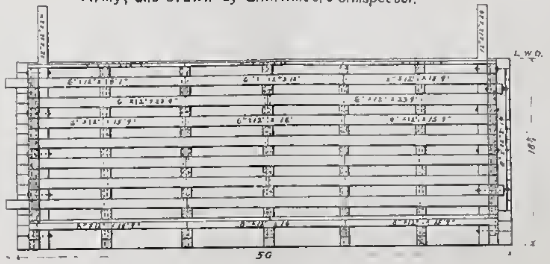

ELEVATION OF CRIB AND SUPERSTRUCTURE, HARBOR SIDE.



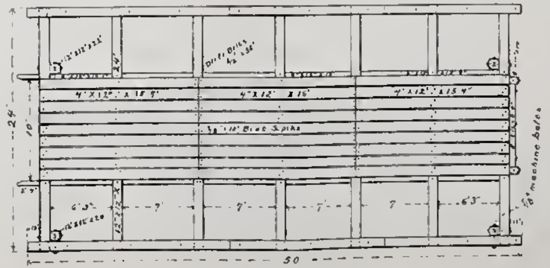

OUTER END, ELEVATION OF CRIB.




CROSS SECTION—CRIB, SUPERSTRUCTURE & EMBANKMENT.




LONGITUDINAL SECTION OF 18½' x 24' x 50' CRIB.




TOP VIEW OF CRIB.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

# ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

## STREETS AND ROADS.

BY HON. JAMES H. MACDONALD, STATE HIGHWAY COMMISSIONER OF CONNECTICUT.

[Read before the Boston Society of Civil Engineers, January 22, 1902.*]

### CITY STREETS.

UPON any business day in the year, if we stand in the center of any of our large cities in the early morning, when the great arteries of trade begin to pulsate, we hear first the distant tap, tap, of the horse's hoof, and the rumble of the wagons starting out upon the day's business, coming nearer and nearer, until finally from every quarter appear horses and wheels. What was at first only a sound has become a reality of living and moving things, in which can be seen trolley cars, light carriages and wagons, great heavy drays, carts, and every kind of freight-carrying vehicles. Every moment of the entire day the pavements are put to the limit of endurance. If you were to count the horses and wagons and amount of freight for which the city street has to find transportation you would be appalled at the result. All day, all the week, and month after month, there is a continual hammer and pound, rattle and jar, on our city streets, and this is continued year after year, and pavements have to be worn out. Flesh and blood cannot stand the strain, horses and wagons have to give up, but others take their places and the strain is continued. But this is not all. Underneath the pavements is a perfect labyrinth of pipes and wire, in obedience to the demands of modern times, so that it has come to pass that our streets underneath the traveled path are as important as the surface. Sewer, gas, water and steam pipes are everywhere; telephone, telegraph and electric wire conduits are being put

*Manuscript received March 8, 1902.—Secretary, Ass'n of Eng. Socs.

down; the cable and trolley cars all combine to do their deadly work to our pavements. Holes are dug here and dug there, and very often the filling is improperly put back into the trenches and the pavement very carelessly replaced. Even if the greatest care were to be taken in putting the material back into the trenches, and if the relaying of the pavement were done as well as possible, it is an impossibility ever to have that pavement in its original condition so as to be a part of, and in conformity with, the grade first established. All of these forces, working on the surface and underneath, seem to be in a conspiracy against, or at war with, our pavements. This state of affairs is in evidence every day, and it is nothing short of a miracle that our streets are in as good condition as they are, with all of these elements at work. These facts certainly furnish food for reflection, and call loudly for the best effort of the engineer to successfully combat these influences that are at work upon our system of city pavements.

To overcome these influences, and to preserve or protect our city streets to-day, requires a heart to conceive, a head to plan, an eye to see, a hand to execute, and the courage of his convictions of every engineer who has charge of the improvements or the care of our city streets, so that we may have properly constructed pavements, which shall, as nearly as possible, meet every condition by which this great question is surrounded.

It will be conceded that, in no department of public works, has more money been spent and practically wasted than in our search for a permanent pavement for our cities. I firmly believe that a permanent pavement for our cities will be found that will nearly, if not quite, answer the demands required of it. I do not think, however, we have that pavement to-day. Every pavement in use in our cities falls short of the requirements in many essentials. We have begun to see what we need, and all of the mistakes we have made, in our seeking for light in the past, will be our best assistants to accomplish the desired result. Engineers cannot do it all, unless they receive the assistance and co-operation of their city administration; and, in addition to the city administration, they must have, as an assistant, every corporation and artisan seeking to occupy our streets. And this is not all; the citizens must give their individual assistance in a ready acquiescence to the demands of trade. How many times have we seen a pavement suitable only for a residential street laid upon a business street, and an expensive pavement laid upon a residential street, where one of less cost would have answered every requirement. In these last-named instances, have engineers fully realized that

"Each man, a world to other worlds half known,
Turns on a tiny axis of his own;
His full life orbit is a pathway dim
To brother planets that revolve with him."

We have practically reached the beginning of what is to be the future city pavements in the six methods of construction now in general use, namely, three in asphalt, one in brick, one in dimension granite blocks and one in crushed stone, the latter known as macadam; and it would be hardly possible for us to return, in any of our large cities, to a cobble-stone pavement, the wood-block pavement, Belgian blocks, or a pavement laid from a distillate of coal tar. These pavements have all been weighed in the balance by the public and have been found wanting.

As I have stated, we have six pavements now very generally adopted in nearly all of our large cities. I firmly believe that, from the six methods of construction named, will be evolved a pavement that will be a marked improvement over any of the pavements now laid.

### FOUNDATIONS.

In the building of any pavement, the two essentials are the surface and the foundation. Every well or properly constructed pavement should be laid upon a proper foundation. In the past, insufficient attention has been paid to the building of proper foundations upon which to lay our pavements. I am not prepared to place the fault at all times to engineers, for many times the actions of the engineer are controlled entirely by others in charge of the work. It has been too often the case in the past that a question of expediency or expense is at fault, rather than obedience to established rules for the proper laying of a pavement. Anyone who has watched the growth of the hamlet into a large and populous city must have noticed the transitions through which this growth has taken place. First a few houses are built near the center, after which the meeting-house is erected, the school-house and the store; then the introduction of manufactories, which called for better and more rapid transportation than the road afforded in the bringing of the raw material and in the sending out of the finished product, namely, railroads. As the little village grew rapidly into a city, the farms which had clustered all around the little settlement were taken up, and the undulated surface was brought to the level required for sidewalks, drainage and the pavements. In this leveling is used an indiscriminate mass of earth, clay, loam, sand, gravel, ashes, and everything that could be found at a reasonable cost to accomplish the purpose. In excavating in all of our large cities we

find such material, which furnishes a very uncertain footing for any pavement that is desired to be placed upon our streets. A single glance at the material excavated from any of the trenches in the streets of our large cities will prove the truth of this statement. With this condition of affairs to deal with, the greatest care must be taken in the building of foundations upon which to lay our pavements. Too often this very essential and necessary care is not given. In the city of Washington, when that splendid system of permanent improvements was started by Mr. Shepard back in the '70's, swamp holes were filled up, and every kind of material was used upon which to lay their foundation. What is the result? Nearly every foot of the original pavements laid by Mr. Shepard at that time has been completely overhauled, new foundations have been laid and a new surface given. In nearly all of our large cities the same lack of wise forethought is in evidence in the foundations of our pavements, showing that much money has been wasted by lack of provision, in the early days, of a proper foundation upon which to lay the pavement.

During the past ten years more attention has been paid to foundations, and we have now in very general use the concrete base; but the trouble with our concrete base is a standard depth, which is rarely, if ever, increased, no matter upon what material it may rest. Commissioners who have to deal with the question of State roads change the character of the foundation with each condition they meet in their work. I wish the same might be said of every engineer who has to do with city work. In the opening up of any permanently laid pavement, and in the cutting down through the foundation to make excavation for connections, there are not enough safeguards or prohibitive measures in the ordinances or in the issuing of permits to men who enter upon any of our city streets to make connections. It is an expensive matter to allow contractors to dig up our city streets and roughly or carelessly throw back the material excavated and improperly relay the pavement. A system of perfect inspection by competent men should be had in every one of our large cities over all work of this kind. The pavement should not be put back immediately. Perhaps a system of heavy planking, properly cleated together, should be placed upon the newly filled opening, and the contractor should be required to assume the care of that opening made in the street for a period of time sufficiently long to insure the proper settling of the material before being allowed to replace the pavement. Even when the material which has been excavated and put back has settled, and is in every way suitable to sustain the pavement, it would

be wise, where a concrete base is required, instead of using cement, to use a mixture of hot asphalt in the assembling of the stone, and the sides of all openings should receive a coat of hot asphalt, so that, when the pavement is finally laid, the whole pavement will become a monolith or a homogeneous mass. It is against all rules of scientific knowledge to undertake to unite the old cement base, that has already been in use, with new work, for at the point of juncture no union will ever take place, and there will be at that point a line of demarkation and a settling in the pavement. I have tried this method of putting back foundations in street openings, and have found it very successful in furnishing a bridging that is less liable to settle.

The greatest care should be taken in providing suitable foundations for the building of all of our permanent pavements. Any pavement, whether gravel, macadam, granite block, brick, block asphalt, rock or sheet asphalt, should have a foundation built sufficiently deep on every sub-grade where it is uncertain whether the existing substratum can properly hold up the pavement.

The day is not very far distant when it will be found necessary, upon the principal thoroughfares in our large cities, to provide subways to contain all of the underground work. Where such subways are used, the pavements will be laid in sections, practically independent, which can readily be taken up and replaced. Pending the introduction of this system, or where it is not used, it might be well to have all connections for pipes made in the gutter lines. As my time is so very much limited, I cannot dwell longer upon this subject, and shall have to dismiss it and take up other parts of this question.

### SHEET ASPHALT.

The three asphalt pavements now in use can be classed as sheet asphalt, most of which comes from Trinidad Lake, rock asphalt and asphalt blocks. I think I can safely say all of these asphalts came into use through the suggestion made by the use of the distillate of coal tar as a pavement, which was very early found to be a failure. The principal objection offered against sheet asphalt is that it is a very slippery pavement. Its slipperiness is largely due to climatic conditions and to the method often employed in mixing the material. In some parts of our country, where the climate is warmer than we find it in the north, east and west, and where there is very little snow, the objection offered is, to a large degree, removed. Sheet asphalt certainly has very many advantages. It is, as we all know, a very smooth and noiseless pavement, a very pleasant pavement to ride over. It very nicely adjusts itself to investigation

in the location of pipes, as holes are easily made to locate all pipes and are readily filled up again. It responds less quickly to defective foundations than do pavements with interstices, because air and frost have no access to the sub-foundation. Offering little resistance to travel, it is very durable. The laying of sheet asphalt pavements can be improved by laying with brick that part of the pavement in use for the gutter and that between tracks and outside of the rails, as is done in some of our cities. An improvement can be made in reducing the cross-slope grade, making the surface as nearly flat as possible, with only a sufficient incline to carry off the water.

Sheet asphalt should be laid upon grades not exceeding 2 per cent. A radical improvement can be effected by a careful selection of the sand used for the body. A great mistake is often made in using practically dead sand, or too fine sand. I do not mean by this to use gravel, but a good, sharp, coarse-grained pit sand. The trouble is that very nearly all of the sand used for building purposes and for street paving is taken from ground of high elevation. Sand so situated is apt to lack that degree of liveliness all sand should have which is to be used in combination with other materials. Certainly a wonderful improvement has taken place in the character of the mixture that is in use now for the wearing surface of our sheet asphalt pavements over that which prevailed in the early days of asphalt paving. Another mistake is made in the "hurry-up process" of requiring asphalt to be laid before the cement concrete is perfectly set, for the evaporation of moisture from the cement concrete has a tendency to make the wearing surface blister and crawl, or warp. If these suggestions are followed, and if the inspectors are employed by reason of their knowledge, many of the objections that are offered will be, for the most part, entirely eliminated. Of course, there is always a hue and cry about pavements being in control of syndicates, corporations or companies, whose only desire is to swell their bank accounts. While this statement may have some foundation, all of these things adjust themselves very nicely by the law of supply and demand. The public is the pendulum which regulates the demand, and the recent experience gone through by men who are in co-operation for the laying of asphalt will satisfy any thoughtful person that high prices and poor work will not be tolerated in the future as they have been in the past. It is neither possible nor wise to deny the public a choice, except where the public desires to legislate for the minority as against the best interests of the majority. Then it is time for those in authority to call a halt.

### ROCK ASPHALT.

Rock asphalt has been laid in cities to a considerable extent, but the public objects to the use of sand, to prevent slipping, as in Paris and other cities across the water, and thus rock asphalt has become somewhat unpopular. There is no question about its wearing qualities, and, when laid in combination with other material, it makes a very durable pavement. Its slipperiness is a disadvantage. I do not know that it will allow the incorporation of other material which might obviate this objection, but it might be partly overcome by means of a roller of sufficient weight, with heat and convex bands, so that indentures could be formed in the surface.

### ASPHALT BLOCKS.

Asphalt blocks have received almost a new lease of life by the substitution of trap rock for limestone as a filler. In the early days of their use for street paving, the filler was principally of limestone, and disintegration took place very rapidly. With trap rock, a very solid, strong and durable pavement is now made with asphalt in the block. When the hydraulic pressure extends further than it now does into the center of the block, it will be difficult to supply a better pavement than one of asphalt blocks.

### BRICK.

Brick pavements have become very popular during the last few years, and, under tests of travel, have developed all of their weak points. There is no test equal to the test of travel in discerning any weakness that is to be found in a pavement. At the convention of brick makers, held some time ago, at which were assembled the representative paving brick makers from many parts of the country, it was openly stated that the burning of the brick to the degree necessary to meet the demands of public travel was yet in its infancy. A brick pavement would be an ideal one for many of our cities if the required amount of toughness could be given to the brick, so that the edges would not crumble under the hoof or the wheel, and the crimping process which takes place would be avoided. In no class of pavements in general use has there been a more rapid advance along this line than in some of the bricks used to-day. It is quite probable that bright minds will find a way of prolonging the life of the pavement by improvements in the shoeing of the hoof and of the wheel.

### GRANITE BLOCKS.

No material used for street paving to-day will stand the test of endurance, under all kinds of hardship, like a granite block. The difficulty is in finding granite blocks with proper wearing qualities.

No granite in use in any of our large cities has borne the test of the Pigeon Cove, or Cape Ann granite, like the test which was given to the granite blocks laid on Broadway, New York City, in 1874. That pavement remained, with all the travel of that public thoroughfare, until 1894,—twenty years,—when it was replaced by a less noisy pavement. The difficulty with granite blocks is the noise, the rattle and jar and the uneven surface. These limit its use to the business centers, where heavy travel takes place. It is quite possible to obviate noise, the crimping of the edges and the rounding up of the blocks, if the sides of the blocks can be brought into the condition of our bricks or asphalt blocks, with smooth sides, so that the pavement may be closely laid. I think that this will be brought about in the near future to meet the demand of the times.

### MACADAM.

I have now reached the last of the so-called permanent pavements, the macadam. Those already named, together with the one I am to treat, are called permanent only because they last longer than others.

More miles of macadam pavement have been laid than of any other. The simple reason for this is that it is less expensive to construct, although perhaps fully as expensive in the end as any pavement I have named. Macadam is not suitable for general use in cities, and, if laid at all in cities, it should be laid only upon streets without car tracks, for it is almost impossible, with the concentration of travel on the narrow area between the rails and the curb, to maintain a macadam road. Macadam requires close attention for its proper maintenance. It requires a semi-moist, yet firm, foundation; a little shade, not too much. It is destroyed very rapidly by too much watering, but it yields a splendid return for the money invested in its construction when it is properly kept in repair; but, if neglected, no pavement so rapidly disintegrates or is so unpleasant to travel over, nor does any pavement require a larger outlay to bring it back to its full degree of usefulness if neglected too long. Methods of construction employed vary in different places. It is astonishing that so little is understood about the construction of this pavement. In a very prominent journal a leading editorial recently stated that "it is too bad, where so much money is being expended for macadam construction, that those who have to do with the matter remove themselves so far from Macadam's methods," and the article expressed a wish that "the people who are in charge of the city pavements would lay a macadam construction such as John Macadam laid, so that the people may

see, for once in their lives before they die, a piece of splendidly constructed road." No doubt the editor was sincere in his statement, but, had there been laid upon the streets of his city a macadam road as John Macadam originally laid it, the editor would have hastened to his sanctum to write an article urging the removal of the officials who gratified his desire. Few laymen are familiar with the fact that Macadam was denied all of the mechanical appliances we have to-day for crushing the stone, for rolling it, and for other operations in the building of our modern macadam road. Macadam to-day, under proper methods, when it has been accepted by those in authority, is immediately suitable for pleasant, safe and convenient travel, while with Macadam's roads it took many weeks of constant travel before the rough stone with which the roads were constructed became fit for travel. The great principle employed by Macadam is followed very closely to-day by men who are in authority over our roads, and the engineers, when they specify a mixed stone method of construction, are as near as possible to the old system or principle inaugurated by Macadam. In the fracture of the stone with the hammer (the method employed to break stone in John Macadam's day), a great many small stones were the result. The stones were all used in Macadam's construction, and the detritus was made by the friction of the wheels on the heavily loaded wagons passing over the stone, which in time bonded the road, the same as with our dust, water and rolling. The condition of our poor macadam roads is due less to want of knowledge in drawing the specifications as to failure on the part of those who construct the roads to follow those specifications and their contract.

Again, many macadam roads are built from trap-dyke stone, where the action of the elements has moved the stone from the parent ledge, and the stone has become discolored and soft, or the faces of the cubes worn smooth. No amount of rolling, no application of dust or water, will successfully compact and solidify such stone. The process of bonding a road from the top with water and dust is the same process exactly as that employed in the paper mill. The pulp for making the paper is distributed into the water run, then picked up on to the rough face of the rolls, and after a series of revolutions over the hot rolls, it comes out through the calendar with all the minute particles assembled into paper. The rough face of the stone of a fresh fracture will remove the dust from the water as it works down through the several courses, and will separate every particle from the water by a perfect system of filtrage if the stone is clean and has a fresh fracture. If the fracture is old or smooth, the water will go right

through all of the courses of stone without relieving itself of any of the particles of dust, and the result is that just a little dust, moistened with water from the sprinkler and pressed down by the roller, is all that remains on the surface to hold the stone together. An examination of the road when just finished will, to the inexperienced eye, suggest that the road is splendidly built. The road may be first class in shoulder construction, solid and unyielding in its foundation, perfect in alignment and in its cross-slope grade, and yet the first team that uses that road will disturb the little covering of screenings and irritate the surface, the wind will quickly remove the top layer or finishing course of screenings, and the whole road will commence to ravel from one end to the other. Such has been my experience on slide trap-dyke stone, and it will be the experience of anyone wherever that class of stone is used; for it is next to an impossibility to hold, or bond, stone of that class unless it is bedded in cement mortar. It is a very difficult matter for those in control of State highway construction to bar out such quarries from competing, and such action would be looked upon with suspicion. Where such stone has to be used, it would be wise to apply a course of screenings on the top of each course of stone before putting on another course, and so continue the process until the established grade is reached. If anything will prevent stone of this class from raveling or making trouble, this method is one that might be employed with some success. The application of clay as a bonding material has been advocated by some authorities. This might do very well for a short time, but the use of anything possessing the characteristics of clay, loam or earth would be a very speedy destruction of the road or of the road's surface. I have never thought wise to use sand between the courses of stone. There is certainly no cementic quality in sand to assemble of itself different bodies and unite them permanently. If sand possessed cementic qualities, it would not be necessary, in the building of houses or any masonry work, to add cement or lime to sand. Sand moist furnishes a wedge which loses its power when dry. Under the impact of the hoof or the jar of the wagon it speedily settles to the bottom of the road, and then the road is broken up, the stone work loses its bonding and the road is practically useless until it has been repaired.

While trap rock is acknowledged to be the best material, there are so many different kinds of trap rock to be found that it may not be always wise to use trap rock. If a combination of two kinds of trap rock could be used, one having good wearing qualities and the other the ability to bond, the result would be a fine wearing

road, satisfactory and inexpensive to keep in first-class condition. While trap rock is the very best material for road construction, by reason of its ability to sustain great stress of travel, and having in its constituent parts iron and lime sufficient to properly unite the cubes, I have seen very fine roads constructed of granite for the bottom courses of the road, with a trap bonding and finishing surface. A very fine road can be built of granite. I have built some such roads in the State of Connecticut, and have seen them exhibit splendid traits of character for public travel. The detritus is formed in sufficient quantity by the travel to keep the road in a fine state of preservation.

The great secret in building a macadam road is in furnishing a bond which will not depend entirely upon screenings to preserve the road in a compact condition. Stone, ranging in size from $\frac{3}{4}$ inch to 2 inches, longest diameter, will furnish a more solid foundation than larger cubes without the small stone. No amount of roller pressure will solidify the road as effectually when it is first built as after it has been used and seasoned by travel. Hence the roads should be built as solid and compact as possible. Another reason for using mixed stone is that roads which do not depend for bonding entirely upon dust will stand neglect better than those bonded entirely with dust. If it were possible to take up a section of road built of 2-inch stone without any of the smaller sizes of stone, it would be found, as the stones are cast into the courses and fall into their places, the sharp points of the stone have bedded themselves into the side or faces of adjoining cubes, and a void will appear which is so protected by the stone in its leaning that no amount of dust will reach the void, and, after the road has been finished, the jar of loaded teams will wear the sharp point, when the stone will naturally slide by and down into the position it should have occupied when originally placed in the road. If smaller stones had been used, they would have formed a shoulder or a support, so that, even with the road becoming dry or the point worn, it would have been impossible for the stone to lose its position, and it would have remained where it originally fell.

In over three hundred sections of highway I have only had, up to the present time, seven sections which have given me trouble, and I have used the mixed stone method since the beginning of my work in Connecticut. Certainly 75 per cent. of the macadam roads built under State supervision during the past seven years have never received any special treatment or attention in the way of repairs, and they are in a good state of preservation. I am building macadam roads 7 inches deep, 4 inches in the bottom

course ranging in size from $\frac{3}{4}$ inch to 2 inches. For the second course I use from 1-inch to $1\frac{1}{2}$-inch stone. All of these dimensions represent the longest diameter, and the depth of stone given is that after rolling. The finishing course is 1 inch of screenings that go through the $\frac{1}{2}$-inch screen. The greatest difficulty with contractors is the temptation, easily yielded to, to put on the screening course in two or three applications. If, when the road reaches this stage of its construction, it is not very closely watched, the screenings will be improperly put on the road, soaked with water and rolled down, and all of the bottom courses will have received very little bonding. Screenings should be applied very sparingly, and should be perfectly dry and rolled in very thoroughly with the roller before any sprinkling is done, and not less than from five to six applications of screenings should be given the road before the final rolling. Under no circumstances should the contractor be allowed to apply the first screenings wet. Where it is possible, it would be well, after the final sprinkling and rolling of the road, to forbid the use of the road for a few days, so that the sun may have an opportunity to harden the road before travel takes place. Where travel is immediately introduced to newly built roads, toe-marks and wheel ruts invariably occur quickly, and these are among the most difficult things to overcome after they have once been formed.

A macadam road should not be built in the early spring or late fall, but this is not always avoidable. I have found the best months in Connecticut to be May, June, July, August and September, for two reasons: first, the condition of subgrade and the large amount of moisture encountered renders it almost impossible to produce that degree of firmness necessary in a sub-grade; second, the sun cannot give to the road that degree of heat necessary in the finishing of a road.

Where macadam is laid with no curbing to retain the stone in the position that it should occupy, it is essential to build a very solid, compact and firm shoulder of the very best material. This very valuable precaution does not receive adequate attention. In the forming of shoulders, the rule with contractors is to line out the road and establish the height of the shoulder, and where shoulders are to be made, to build the shoulder material flush up to the line, instead of allowing the material to leak over into the traveled part not less than from 8 to 10 inches. This gives an opportunity for ramming the shoulders down good and solid and then cutting back to the line, thus forming a good, firm edge to work to. When shoulders are thus made, the metal used in the roadbed

is retained in position, and does not work out into the shoulders, robbing the road of material that properly belongs to it.

### ROLLING MACADAM.

Another wrong method of construction is to roll down the center first and finish up with the center rolling. The first method has a tendency to flatten out the road and to destroy the proper cross-slope grade. When the finished road has been tested by the engineer and found deficient along the center line, only one of two courses is open to the engineer to bring the road up to the established grade—either to disturb the entire surface or to put on an additional quantity of screenings. It is seldom that the first course is resorted to, but too frequently the latter. A road brought up in this way with screenings will always be an object of great solicitude and an expensive road to keep in good repair.

The practice of center rolling has a tendency also to leave the outer edges and three or four feet of the macadam very loose in their construction, while the center, when the road is first turned over for travel, is the best part of the road, which by use in a short time breaks its bond and works out towards the sides, and then trouble commences. In building macadam or any other pavement there are no little things, from the ploughing up of the road to the last rolling the road receives. Very much depends even on the dumping of the load of metal in the roadbed. Under no consideration whatever should a load of stone be allowed to be dumped on the roadbed proper, unless every part of the load, before rolling, is removed and placed with shovels in the place it is to occupy, for the simple reason that, when dumping is resorted to, whether from a cart or from a reach wagon, uniform roller pressure cannot be had upon all parts. The part which is brought to the established grade by shovels will respond to the rolling, but where the body of the stone fell there will be resistance, which in time will develop a weakness in the road. Every part of the road should receive equally the same amount of roller pressure. Every part of the road is dependent upon every other part, just as the smallest rivet in a Corliss machine is as important as the great wheel that moves the belt to turn the wheels in the entire factory. In road construction, if the simplest detail is neglected, the result is fatal to the road; so the utmost care must be taken in every step of construction if we are to have first-class work.

### TELFORD.

I have used telford only in special cases, where the foundation was uncertain. A 13-inch telford road will not wear as well

as a 7-inch macadam road upon a gravel or mixed earth or sand foundation. The rigidity of the 13-inch pavement conduces to the destruction of the road, while the elasticity of the foundation of a 7-inch macadam tends to its preservation; so I have not extended the system of telford roads any farther than was absolutely necessary, preferring to use good sub-grade material, with plenty of rolling, and to extend my system of macadam at a less price than if my roads had all been of telford construction.

### INTER-TOWN ROADS.

While I have named macadam in the family of permanent pavements used in our cities, I think it is destined to be more popular as an inter-town road than as a city street; but, as my time is very limited and the subject is so prolific, so full of suggestions, I shall have to leave the macadam treatment and speak of other inter-town roads.

It is only a few years since highway improvement was given any intelligent basis. I have never met a man who did not firmly believe in good roads. It is true that there has been objection to the transfer of highway improvement from local to State or county officials. This is not strange, and it should be taken not as evidence of opposition to road improvement, but rather as an indication of local patriotism. However, the greatest improvement in highway construction along permanent lines has been made since the inauguration of State commissions, in which men of wide experience in highway improvement have been placed in charge of the expenditure of money which theretofore had been unwisely used by local officials in town or county road construction. This departure has found favor with the American people, who require some time before placing their entire confidence in a new movement; but, once it has been placed, it is there to stay. Only by the prostitution of the office of commissioner in the disbursement of money, or by inefficiency, will the commission forfeit the confidence of the people of the State, and the road improvement now so successfully inaugurated be retarded in its growth.

I have watched with deep interest the wonderful progress made by the Massachusetts Highway Commission, and have seen the constructions laid by them. Massachusetts has made a splendid beginning, and it is to be hoped that the able management shown may be continued along the lines so well begun.

It would be difficult to outline any method of highway improvement to be rigidly followed by every town, every county and every State in the Union. No standard work in print to-day

will equip the engineer with that degree of information necessary to treat every condition of road construction by which he may be confronted. Conditions change, in climate, in the material to be used, in accessibility to railroad facilities, and in a thousand and one things which do not always appear to the man who writes the text-book. Text-books are necessarily written from the point of view, the experience and the conditions surrounding the author. While he may adapt himself to those conditions, every engineer, in taking up this great question, will find that every day is a development, every day a going to school. New features are continually requiring his most careful thought and consideration. What he might outline as the proper thing to be done in one place would not be right treatment in another. In some of our States the low-lying plain predominates; in others there is a preponderance of stone. The coast line suggests one character of road, the valleys another, and the mountainous parts of the State another. In one is found plenty of stone, remote from railroads and from a crushing plant, while in another State no stone is to be found, but plenty of gravel is to be had on every side. In still another State we find the sand plain, with neither stone nor gravel. In some places a heavy depth of clay is found everywhere. In Kansas we have 7 feet of solid black loam, with no stone. In California many parts of the State are all sand. All these require different methods of construction. Often an engineer finds himself embarrassed by lack of money. A good rule is to lay that class of road that will most nearly meet the conditions obtaining in that immediate vicinity. It is always unwise to import material, or to establish a method of construction that will overburden the people financially to extend it or to keep it in proper repair. In districts with very little stone, and in towns remote from railroads, where plenty of stone is to be found, but no crushing facilities, it is well to lay gravel roads, if gravel is obtainable. I have also found it wise to anticipate the system of general grade reduction in Connecticut, lifting up the levels, straightening the roads, removing the rocks from the roadbeds, and familiarizing the people as quickly as possible with good roads, pending the future general improvement. This plan gives to the people the immediate use of the road and safe travel to their nearest market.

## DISCUSSION.

*Question.*—What do you mean by "trap dyke" stone?

*Answer.*—Slide rock. Stone that has fallen away from the parent ledge, less than 6-inch cubes, where the accumulated dirt on the faces of the stone deprives the screening of its cementic

property, or where the stones have worn smooth, so that the stone does not take up from the water the detritus necessary to properly bond the road. These small stones that have broken off and fallen down are so small that they pass through the crusher, and there is, of course, no fresh fracture, so that it is impossible to assemble stone of this kind with the material used for bonding.

*Question.*—Have you ever seen old sod used on a country road?

*Answer.*—Yes; I have seen it lying all over the traveled part of a road in large clods. Some time ago I discovered some roads made in this way, and learned that an inspector was to come in from an adjoining town to pass upon these roads as finished. Being a little curious to know how the inspector viewed this way of building a road, I inquired, on my next visit, whether the inspector had looked over the roads. The town official said, "Yes, and passed all of them." This was not State work, but one of the town methods of road construction. I have used sod in one town, where there was very little stone to be had—in fact, very little material of any kind with which to construct a road, and where the expense of importing stone was prohibitive. The road I had to treat was a sand plain, with about 12 inches of sand on it, and I specified taking old sod, inverting it and putting it across the entire road as the first course on top of the sand, then using some mixed earth and rock for the second course, with a slight covering of sub-soil found under the black loam, rolling each course down as the work progressed. This made a very fair road, although it is not embodied in any of our State specifications. It was used simply to avoid a very unpleasant section of highway.

*Question.*—Are the wheelmen assisting road improvement?

*Answer.*—Yes, sir. The wheelmen have always been very warm friends of the good roads movement, and I know of no other factor that has had so great an influence in bringing about State supervision, assistance and control in our State. Their painstaking and hearty co-operation has given rise to the strong sentiment in favor of road reformation.

*Question.*—What size stone would you use in repairing an old macadam road that has been broken up?

*Answer.*—After I had accepted the invitation to address your Society, and had forwarded my topic, I found that I could not, within reasonable limits of time, treat the question of care and maintenance as fully as I should have liked. In the first place, no road should be allowed to be broken up. In maintaining a macadam road it is unwise to put on screenings, for, if a macadam

road is properly built there is no necessity for the application of screenings. Screenings placed upon an old macadam road must lie upon the top of the road, where in dry weather it is dust and in wet weather it is mud. The time to repair a macadam road is when the stones begin to show bare, when the screenings or wearing surface of the road has been lost. Then, instead of screenings, stone ranging in size from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch, longest diameter, should be used. If the $\frac{3}{4}$-inch stones are spread upon the surface of the road, over the full width of the traveled part and to the depth of about $\frac{3}{4}$ inch (no greater depth should be applied), they will not need water or rolling. The point of contact will be so near the point of resistance that the full crushing force of the hoof or the weight of the load upon the wheel will fracture the stone. The fracture will yield just a small amount of dust, or detritus, which falls quickly to the under surface and is protected from the heat of the sun so that it will not dry out, and from the wind so that it cannot blow off. In a very short time the ordinary travel will reduce all of this course and a gradual healing process will go on over the entire surface. I have tried this method in Connecticut, and have not found a single failure. It yields a very large return for the money invested. The question asked is answered in this description of repair; but, if a road has broken up, there is only one thing to do, and that is to apply whatever stone is necessary, and, of course, go through the process of screening, wetting and rolling. It is never necessary to put picks upon steam rollers and pick up a whole macadam surface, for the simple reason that no macadam road should be allowed to get into such a condition under an intelligent system of repairs.

*Question.*—Would you use splinters or trap rock, such as you described, the $\frac{3}{4}$-inch size, in re-surfacing, on a grade of 8 per cent., in preference to dust?

*Answer.*—Most assuredly. Dust applied on an 8 per cent. grade would not remain upon such a heavy grade very long after the first shower of rain, and, when the shower of rain was over, all that would remain upon this 8 per cent. grade would be the small particles of stone contained in the dust. The dust would be in the gutter. The weight of the stone would help to resist the force of the elements, and insure some return for money invested in its application.

*Question.*—What minimum grade for gutters on gravel roads do you think is right to establish?

*Answer.*—The minimum grade that we have adopted in Connecticut is 1 per cent. Earth gutters do not carry the water very

quickly. Under certain conditions we have been forced to allow a less per cent. of grade, but it is always under protest.

*Question.*—Do you ever use screened gravel?

*Answer.*—Yes; we have used screened gravel in Connecticut, but only once in my whole official career, and I think it safe to say it will never occur again. The screening of the gravel has a tendency to remove its bonding property. Gravel must have, as a constituent part, a sufficient bond, or it is a waste of money to apply it. It is true that we do not find in every place suitable gravel for building gravel roads. We often have to use gravel deficient especially in bond, and such gravel must be given an admixture of clay or sub-soil. Only that gravel should be used which requires a pick to dislodge from the bank. Gravel which is solid and compact in the bank, free from stratifications of sand, is very generally a safe gravel to put upon the road. It is the policy of my State to use the material found in the town so far as it is possible and economical to use it. We do not import material if we find suitable material in the town. So the building of gravel roads has become a part of our State system. For intertown roads I prefer a good gravel road. It is inexpensive to construct, it does not require expensive machinery or scientific road builders, and it is very easily and economically kept in repair. It is a cool road in summer to drive over, and it is not unpleasantly loose in its character in the late fall and early spring. As a rule, it is a good, serviceable road for all seasons of the year, when it is built well and of suitable gravel.

*Question.*—Do you think a road scraper is a good thing to use upon the roads, especially earth roads, or what tool do you think is best to round up and shape an earth road?

*Answer.*—I think the very best tool to use upon an earth road is a road scraper, although I regret to see the use of the plough becoming a lost art. The road scraper may be so handled as to put back upon the road the gutter-wash and worn-out material, making it do service over again where it has already been used too long. It is the abuse of the road scraper, and not its use, which is to be condemned. I know of no other tool with which so much work can be done for so little money as with a road scraper when intelligently used.

*Question.*—What is your maximum grade?

*Answer.*—In the State of Connecticut the standard maximum grade is 5 per cent., but in some parts of our State we are compelled to exceed this standard, in order to avoid excessive expense. In

other words, we accomplish just as much grade reduction as it is possible to get.

*Question.*—Do you allow less depth of stone where different kinds of material are found in the sub-grade?

*Answer.*—Certainly. The standard for macadam treatment in our State is 7 inches. The first course is 4 inches; the second, 2 inches, and the last, or finishing course, 1 inch. Where the material is springy on the line of the proposed highway, we furnish a telford base of 8 inches and a macadam top of 5 inches, making 13 inches over all. On a gravel foundation we have used a 5-inch treatment, 4 inches of macadam and 1 inch of bonding and wearing surface. Upon some of our roads we have used a foundation of slag, with a 2-inch treatment of crushed stone and 1 inch of screenings, making a very good road. Our engineers put on the profile, for my information, the character of the material found at each station, so that we can intelligently select the most economical treatment.

*Question.*—When you allow between certain stations a less depth of stone than between others, what is the depth of stone allowed at the point of juncture, and do you change abruptly from one depth of stone to the other?

*Answer.*—No. The change is gradual from one depth of stone to the other, so that there is no possibility of breaking away or breaking down.

*Question.*—Do you use steam rollers on gravel roads?

*Answer.*—We use both the steam and the horse roller on our gravel roads. A contractor is allowed to use either. We specify that the contractor on gravel construction can use such roller as shall be allowed by the Highway Commissioner. If a contractor has a steam roller, he naturally prefers to use it, as it effects a great saving of time in the firming of his road; while, on the other hand, if the contractor has a horse roller, we allow him to use that. A gravel road well rolled with a horse roller gives very good service. So we leave the question open.

*Question.*—Do you ever find the frost enter your stone work from your shoulder sufficiently to break up the road at that point?

*Answer.*—No; I never have noticed any trouble with the frost at this point. It is well, however, to see that the shoulder is well built and the edge of the shoulder cut down square and true to the line, so that the stone may not have as a fulcrum the material composing the shoulder to lift up the stone out of place. Not enough attention is paid, as a rule, to the importance of properly constructing a shoulder. A good shoulder is a very important

matter in keeping the road in condition. If a shoulder is weak, it allows spreading of the material. If it is strong, constructed of good material and well rolled, it retains the material in its original position, and there is no danger of breaking down the road.

*Question.*—What is the standard width of your State roads?

*Answer.*—The minimum width of our State roads is 12 feet for the traveled path, but the standard width of our road is 16 feet. We build more standard width roads than any other width. Some, of course, we make wider than 16 feet, where conditions demand it; but, as a rule, the traveled part of our roads is 16 feet wide.

# HIGHWAY CONSTRUCTION.

By E. R. Buckley, Ph.D., State Geologist, Rolla, Mo.

[Read before the Engineers' Club of St. Louis, February 19, 1902.*]

The permanent improvement of all public thoroughfares, whether they be situated in the midst of a crowded city or in the rural districts, is a condition which we must look forward to as a necessity. Every person who keeps abreast of the times and notes the progress of this new century feels that every avenue of commerce demands rapid, clean and quiet facilities for transportation. This demand is fast crowding itself upon us, and with it come problems for solution both by the citizen and by the engineer.

This demand for clean and quiet pavements and rapid transportation affects the construction of both pavements and vehicles; and it is evident that improvements in both must go hand in hand if we would realize most quickly and economically the desired results. Any improvement which may come about in the construction of vehicles must be the result of individual or corporate interest; but the improvement of the public thoroughfare must have its birth in the national, state, county, town or city administration. The public highway is a commodity used in common by the people, and consequently cannot be adequately administered except by the city, town, county, state or national government.

Some people believe that certain of the highways should be under national, and others under state control. Others are as firmly of the opinion that the county, city and town should control all public highways. By whom the highways should be controlled, improved and maintained is a question with which we are now confronted and with which we shall undoubtedly be confronted for years to come. Personally, I feel that there should be a system of transcontinental highways, constructed and maintained by the national government; and that state and county highways, as well as city and town streets, should be improved and maintained by the state and county. However, this question of control and administration of public highways can scarcely come within the scope of this paper, and will be passed without further consideration.

Another matter which presents itself is the manner in which the improvement and maintenance of public highways shall be

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paid for? Shall the public, as county, state and city, the individual citizen, or all be taxed for these improvements? This is a matter which involves the equitable distribution of the burden of taxation, and is also outside of the scope of this paper.

The third problem with which we are confronted is the character of the pavement to be constructed and the method to be employed in constructing such pavement. The kind of pavement constructed depends very largely upon the location. Owing to the very different traffic conditions to which city and rural highways are subjected, they are usually considered separately, as constituting somewhat distinct problems. However, the improvement of a highway, wherever it may be located, has, as its main object, the reduction of the cost of traction. Perfection in construction and durability are everywhere limited by the cost of construction and maintenance. It is my purpose to-night to confine myself to a discussion of city pavements.

St. Louis has over 100 miles of granite block, asphalt, wooden block and brick street pavements, costing over $6,700,000. She also has nearly 36 miles of alleys, improved with granite, granitoid and brick pavements, costing over $650,000. Besides these there are about 350 miles of broken stone pavements, including macadam and telford, in the construction of which limestone and novaculite have been used. The report of the Street Commissioner for 1901 shows 436.46 miles of streets and 204.07 miles of alleys still unimproved. For the fiscal year ending April 8, 1901, the cost of cleaning and repairing streets and alleys amounted to $335,484.87.

The importance of this department of municipal administration is clearly evident from the foregoing figures. The past record of the city of St. Louis, like that of many other large cities, has been brilliant with mistakes in the matter of street improvements. These mistakes have been in the nature of experiments, and their recognition is a sign of progress which bespeaks better conditions for the future. It is not necessary for me to discuss the reason for these mistakes. They are past and paid for. May the limestone macadam rest in peace!

Before entering upon a discussion of the merits of the different pavements, I desire to remind you of the personal responsibility which we have in all matters of public administration. We are living under a democratic form of government, and we must remember that, when we condemn the administration of public affairs, it is not only the administration, but our neighbor and, perhaps, ourselves that we condemn. Remember that the govern-

ment of the people in the United States lies in the consent of the governed. If the government is poorly administered, taxation unequally distributed and public funds squandered, we must, whether interested or not, bear our share of the responsibility,—our share of the burden.

Yet, I would not have you feel that I am condemning the form of government under which we live, for there is no system which is better adapted to the needs of our population than that by virtue of which the United States exists to-day.

It is the duty of every citizen to acquaint himself with the manner in which the different municipal functions are administered. Electric and gas lighting, water supply, street railways, telephone system and street pavements, all should receive the careful attention of the citizens of every community in which these luxuries have become necessities. This attention should be given through clear glasses and not through goggles colored with political daubs which distort the object viewed and change everything into emerald green and royal blue.

I feel that it is somewhat presumptuous in me to come before this Society of Engineers to discuss a subject with which every member is familiar. I have every reason to believe that, with perhaps a few exceptions, every person in this room, were he given the opportunity, could construct pavements which would be ideally fitted to every condition which presents itself on the streets of St. Louis; provided, first, that he had an unlimited appropriation at his disposal for construction and maintenance; and, second, that he were given police protection that would insure him against injury by indifferent, selfish or maliciously inclined persons. With an unlimited appropriation for construction and maintenance, and the ability to remove traffic from the streets during the time of construction, an honest engineer can construct a sanitary pavement which will be at all times comparatively clean and noiseless. The two most serious problems connected with street paving are (1) how to obtain the money necessary for these improvements, and (2) where can men be found who will administer these funds honestly and for the best interests of the community?

The engineer or street superintendent is called upon to construct a pavement which is noiseless, clean, durable and inexpensive, and one which will not need cleaning or repairing for a period of ten or fifteen years, all at $2 per square yard. It is, of course, unnecessary for me to add that this, at present, is beyond the capacity of any engineer. If the expense permissible

for construction and repair were unlimited, a solution of the problem could be much more nearly reached.

In 1892 W. J. Ogden said that "if quiet, cleanliness, beauty and the highest degree of durability and safety could be combined in one kind of paving material, at a reasonable cost, that material would be the pavement of the future." But he adds, very properly, "by a strange persistence in the nature of substances, things that are hard are noisy when hammered, and only those things are noiseless which are soft and yielding. Where noiselessness is important, durability must be partly sacrificed."

Very few engineers, except in the larger cities, have an opportunity to construct pavements which are in accord with their experience. In the first place, the city engineer is not given sufficient opportunity to inspect the pavements of other large cities of the country. He may be a thoroughly competent man, of scientific attainments; but, in order to be most useful to the municipality, he should be given time and opportunity to study the improvements in other cities. In place of this, however, if pavements are to be examined in New York, Boston or some other city, a committee of aldermen is selected to perform the task, while not infrequently the city engineer remains in his office to await their report. He is often looked upon as a sort of draftsman, who draws plans and writes up specifications in accordance with the ideas of the street committee of the board of aldermen.

I knew a number of city engineers in Wisconsin who could not tell you how the pavements in the nearest neighboring city had been constructed, or the difficulties which were being experienced in their construction and maintenance. This is not the fault of the overworked engineer, but of the city administration, which reserves as its own legacy the privilege of taking "junketing" trips to neighboring or distant cities.

What value comes to the city from a "junketing" trip by a committee of aldermen? When they return, can they tell you anything important about the pavements they have inspected? Committees of aldermen from other cities have visited Madison, Wis., my former home, to examine the macadam pavements. They have been driven over the most beautiful, newly paved avenues; have been royally entertained by the city; and have returned home to report that limestone macadam, the muddiest street in wet weather, the dustiest in dry weather, the cheapest to construct and the most costly to maintain, was the ideal street for their city to adopt. This mistake might never have been made if the city

engineer had been instructed to make a thorough investigation, quietly and alone.

Under the present municipal conditions the alderman is an important man, who sometimes allows the wishes of his constituents to influence his judgment. An influential citizen may have heard of some pavement which has worn well, or perhaps has seen a pavement that looks well; and, without regard to the traffic conditions on the street to be improved, insists that the street on which he lives shall be improved with this kind of pavement. *A man must know a pavement under all conditions of climate and traffic and at different periods of its life* in order to pass judgment on its qualities. Not knowing this, the opinion of the citizen has but little value. The engineer, however, although knowing better, must acquiesce to these influences rather than antagonize the political interests which might work to his own detriment.

Corporations owning street franchises and companies interested in the manufacture of paving materials are not free from bribery and blackmail. Engineers, also, I regret to say, are not always adverse to making commissions, on account of which inferior materials are sometimes recommended. However, when it comes to the question of corruption, I would trust a citizen or an engineer sooner than an alderman. I speak from experience in this matter. I have been an alderman, but I have never been a city engineer.

Any standard pavement can be constructed under any conditions which may exist in any city, and it can be constructed with as great a degree of perfection in one city as in another. It is possible to construct as perfect a brick pavement in St. Louis as in Chicago; as perfect an asphalt pavement can be constructed in Boston as in Louisville. The same may be said of stone block, macadam or almost any other of the numerous pavements which are now being recommended. I do not say that an asphalt pavement, under the same traffic condition, is as durable in Buffalo as in St. Louis; neither do I wish to have it inferred that the cost of construction will be the same. Too often pavements which are durable under certain conditions are constructed on streets on which the traffic conditions are such as would lead one to conclude, from the condition of the pavement, that it was ill adapted to any street.

It is folly to construct any but the best of any pavement which may be selected. If brick is chosen, let it be the best-known brick pavement, constructed on the most approved plan; if asphalt, let it be the best asphalt. The additional cost of con-

structing the best pavement is always compensated by the lessened cost of maintenance.

The first, and perhaps the most important, question which presents itself in connection with the improvement of any street is the selection of the kind of pavement to be built. To settle this, one must know the qualities required, the initial cost of construction and the estimated cost of maintenance.

After one has determined whether the pavement must be smooth or rough—quiet or noisy—he should investigate and consider carefully the cost of maintenance. Selecting first those pavements which by experience have demonstrated that they possess the desired qualities, the matter of selection becomes a question of dollars and cents; a question as to which pavement will prove least expensive, considering both the cost of construction and the cost of maintenance.

So great is the variety of atmospheric and traffic conditions to which a street may be subjected that one can without difficulty find conditions in some part of this broad earth which will admit of the construction of each of the recognized classes of pavements. Brick, granite block, macadam, asphalt, tar macadam, wooden block, glass block, asphalt block, each has a place, if it can be found, for which it is especially fitted. If such were not the case, it would never be constructed. Do not construe me into saying that there is a place for all kinds of wooden block, all kinds of granite block or all kinds of any other pavement. *No*, there is no place for poor brick or asphalt, inferior macadam or imperfect wooden blocks. There are conditions, however, under which the best of each of these pavements should be used in preference to all others.

It is customary to divide streets into three general classes, based on traffic conditions. These classes are residential, light business traffic and heavy business traffic. Residential streets are subject to a much lighter traffic than the other two classes, and may, consequently, be paved with less durable material and yet last as long and cost less than the pavement designed for streets of the other two classes. Strength and durability in pavements designed for residential streets are usually sacrificed for quietness, cleanliness and beauty. A pavement, such as is used on a residence street, might be very short-lived on a heavy traffic street, and yet, in its own place, outlive a strong and more durable pavement constructed in the business section of the city. On a residential street the pavement should at all times combine the essential qualities of quietness, cleanliness and beauty, which are

not infrequently absent from the pavements thought to be best suited to withstand heavy traffic.

Light business traffic streets should be paved with materials which will reduce, as far as possible, the noise and dirt of the street, and yet maintain a standard of durability equal to that of the quieter pavements constructed on residential streets.

Heavy business traffic streets require primarily a strong and durable pavement, and all efforts thus far have been directed toward the construction of a pavement which will withstand for the longest time the heavy business traffic which the street is called upon to accommodate. Thus far very little attention has been paid to the noise and dust which are often characteristic of these pavements. All the thought and attention of the time has apparently been centered upon strength and durability, and thus far the success of a pavement has been measured by its lasting qualities. Only in proximity to schoolhouses, libraries, court-houses and hospitals has there been any notable attempt to reduce the noise by the use of smoother pavements.

On heavy business traffic streets the pavements have been looked upon mainly from the standpoint of the taxpayer; very little consideration being given to the convenience of the public. The noise, caused by the ceaseless rumbling of the cars and the pounding of ponderous wagons and heavy horses, and the inartistic effects of the construction, have been given only the remotest consideration. The demand which is arising among the large wholesale houses for quieter pavements in front of their places of business is purely the result of a process of reasoning by which they believe that it will increase their business by bringing more people on to the street.

The effects which the different pavements have on the life of vehicles and horses have been given but passing attention. The horses and wagons driven over the streets may be likened to battering-rams used against the wall of a city. Those who build the pavements correspond to the people within the walled city, who build their walls with a knowledge of the agents of destruction. Those who own the vehicles and horses may be likened to the attacking army, which, knowing the character of the fortifications, provides itself with weapons that will not wear out through the attack.

Those who buy vehicles and horses know that they must be strong in porportion as the pavement is unyielding and rough. Thus it has happened that the introduction of certain kinds of street pavements has compelled the use of vehicles especially

constructed to withstand the jolting and pounding which the pavement incurs. Vehicles which are driven over hard, rough pavements cost more than those which are used on smooth and elastic pavements. Horses are often rendered useless by a few years' service in some of our large cities. The average period of usefulness of horses used by one of the transfer companies in Chicago is reported to be from 4 to 5 years.

A railroad company levels its roadbed and removes the curves not so much to increase the speed of its trains as to reduce the cost of maintaining the track and the rolling stock. The most important problem before the railroad engineer is to reduce to a minimum the cost of maintenance of both the roadbed and rolling stock. The problem before the city engineer is the same,—the reduction to a minimum of the cost of maintenance, of the pavement and of the rolling stock. The time is near at hand when in constructing pavements we must consider the user as well as the builder. When this time comes, we will build cleaner, quieter and more beautiful superstructures than at present.

During the last year I have been investigating the effects of different kinds of pavements on horses and vehicles used by transfer companies, wholesale houses, livery stables, etc., in the larger cities of the United States. The results of these investigations have not yet been compiled; but, from reading them over, I am convinced that the different pavements, as regards the number of years that a horse is serviceable, will rank about as follows:

(1) Wooden block, (2) macadam, (3) brick, (4) stone block and (5) asphalt.

With respect to the serviceability of vehicles, it appears that the different pavements rank about as follows:

(1) Asphalt, (2) macadam, (3) wooden block, (4) brick and (5) stone block.

The period of serviceability of a vehicle driven over city pavements ranges from 3 to 20 years, averaging about 9 or 10 years under the most favorable conditions. The repairs necessary during this period result largely from injuries sustained while being drawn over granite block pavements. Injuries sustained by vehicles when drawn over sheet pavements result very largely from turning out of the street car tracks and are not due to the character of the pavement.

This investigation, which is not yet complete, will show, I believe, that a smooth pavement which does not become slippery with wear is in reality the cheapest for the user as well as for the builder. I believe that the injuries sustained by horses when

driven over smooth pavements are fully compensated by the less injury to the vehicles and the greater convenience and comfort in riding.

Let it be understood that in using the term "smooth pavements" I do not refer to sheet pavements in particular. I believe that the roughness of block pavements is in a large measure unnecessary, and that, except where the grade of the street is steep, it should be eliminated as far as possible. I might further add that, except in strictly residential districts, the grades can often be so reduced as to obviate the necessity of specifying block pavement.

As previously stated, the streets of a city are usually classed as residential, light business traffic and heavy business traffic. The class under which any particular street falls can usually be determined without making observations and reducing them to a quantitative basis. In cases where there is doubt as to the class to which a street belongs, this can be determined by actually counting the vehicles of different kinds which pass over the road at different seasons of the year, always bearing in mind that, when once improved, the traffic on the street will increase in proportion to the facilities afforded by the improvement.

One of the first observations to be made in the construction of a pavement is on the nature of the soil constituting the subgrade. Provision must be made to remove, both from the subgrade and the surface, all surplus water. This is accomplished, as you know, by subsurface and surface drainage. The different types of subsurface drains are illustrated in all standard publications on highway construction. Their size and shape, and the depth at which they are laid, will depend on local conditions. What it is desired to accomplish by drainage is to provide conditions under which the pavement will be dry at all seasons of the year.

Gas pipes, sewer mains, water pipes, electrical conduits and all underground constructions should, if possible, be completed before a street is paved. It should be made a part of the franchise of every corporation that they extend their services through every street which is to be paved before such pavement is constructed. The tearing up of a pavement once constructed is liable to do more damage than five years of wear.

The classes of pavements which I believe may be profitably considered in this discussion are asphalt (sheet, rock and block), brick, stone block, wooden block, macadam (including telford) and tar macadam. On heavy business traffic streets only three

kinds of pavement have demonstrated that they are entitled to be considered, under present conditions; namely, granite block, asphalt and brick. From the list given above, macadam, wooden block and tar macadam are rejected as undesirable. For light business traffic streets, asphalt, brick and wooden block should receive consideration. For residential streets, asphalt, wooden block, macadam and tar macadam should be given consideration.

The granite block pavement, as now constructed, should be confined to heavy traffic streets; and I know of no pavement which is so well adapted to withstand heavy teaming in the business section of the city as granite block, when properly constructed.

Specifications for granite block pavement should provide for smooth heads and close joints. The time when stone blocks, with rough heads and half-inch joints, should be accepted by any city has passed. Granite block pavements, like all other block pavements, should be laid on a concrete foundation. This foundation should be built of Portland cement and crushed stone, and should be protected from traffic until thoroughly hardened. The joints should be filled with the best Portland cement grout, and all traffic—street cars and vehicles—should be removed from the street until the cement has hardened. It is absolutely *senseless* to require a block pavement to be grouted unless this precaution is strictly adhered to. There is only one condition under which street cars ought to be permitted to run on streets being thus improved,—and that is when the street car company has reconstructed its road bed, laying the ties in concrete on a concrete foundation. Another suggestion to those who may hereafter have to deal with the granting of franchises,—see to it that every franchise granting to street railway corporations the use of the public highways contains a provision whereby the city may compel the company to abandon the use of highways during a time when they are being paved or otherwise improved.

The ordinances protecting the contractor in his attempt to remove traffic from a newly paved street are often so inadequate or so ineffectually enforced that it is next to impossible to properly construct a block pavement. Barricades are often removed, at the convenience of some delivery clerk or drayman, on account of which thousands of dollars of damage are done in a few hours. It would pay a city to employ special policemen to patrol newly paved thoroughfares, under instructions to arrest any man who attempts to drive beyond the barricade, under penalty of the confiscation of his team and wagon. I am thoroughly convinced

that the executive departments of many of our cities do not fully appreciate the damage, in dollars and dimes, that results from the indifference of policemen and others to this very necessary precaution. What is true with reference to granite block pavement is equally applicable to brick, asphalt block and wooden block, and, to a less extent, to the other pavements.

Referring to granite block pavement, I wish to emphasize what I have already said relative to its efficiency as a material for paving streets which are subjected to heavy traffic. Many of the Eastern cities, conspicuous among which may be mentioned Boston, have come to use granite block almost exclusively on streets which are subjected to heavy traffic. It has been very well demonstrated by experience, in Buffalo and other cities, that both asphalt and brick are more expensive on such streets than granite block. Asphalt, of course, has the advantage of being somewhat quieter, and, when properly maintained, is much cleaner than either of the block pavements mentioned.

I have in mind a striking instance of the comparative durability of a standard paving brick and granite block pavement. In Milwaukee the heavy wagons from the Pabst brewery are driven from the warehouse to the railroad depot, over Chestnut street, which, two years ago last summer, was paved with vitrified brick selected according to the most rigid tests ordinarily applied. Last summer I went over this pavement in company with the assistant city engineer, and, to my astonishment, found that the heavy teams had actually worn deep ruts in the pavement, on account of which some of the brick were only one-half or one-third their original thickness. An examination of the granite block pavement, on the roadway leading from the street to the warehouse, showed that, although it was several years older than the brick pavement and subject to the same traffic, it was but very little worn. In the same city I have observed asphalt and granite block pavements, constructed the same year and subject to the same traffic, the former of which were very badly rutted, while the later remained but little impaired.

From observations made in different cities, I have concluded that, as yet, for heavy business traffic there is no pavement less expensive than granite block.

Of the asphalt pavements there are three kinds: sheet asphalt, asphalt block and asphalt rock. As a rule, these pavements should be constructed, as in the case of a block pavement, on a concrete foundation. You are all familiar with the standard method of constructing these pavements. The St. Louis specifi-

cations call for a concrete foundation of 5 inches, a binder course of $1\frac{1}{2}$ inches and a wearing surface of $1\frac{1}{2}$ inches. To insure the best-wearing surface, the utmost care should be exercised both in the selection of the materials, comprising the wearing surface, and in the method of mixing. The specifications used in St. Louis call for from 12 to 15 per cent. of asphaltic cement; 70 to 83 per cent. of sand, and 5 to 15 per cent. of pulverized carbonate of lime (limestone). The asphaltic cement should be a mixture of refined asphalt and heavy petroleum oil free from coal tar or other inferior bituminous products. The sand should be of quartz alone, and not a mixture of calcium carbonate and quartz, as is frequently the case. It is my impression that the wearing capacity of asphalt would be improved if pulverized granite or quartzite were substituted for the limestone. It has been demonstrated, to the satisfaction of most engineers, that limestone is one of the most injurious constituents introduced into an asphalt pavement. The asphalt is itself somewhat easily decomposed through atmospheric agencies, while the carbonate of lime is very susceptible to decomposition.

In the use of asphaltic stone, care should be taken to reduce to a minimum the percentage of calcium carbonate, for the reason given above that calcium carbonate is injurious as a constituent of sheet asphalt pavements. Asphaltic stone is both of the limestone and sandstone varieties. The limestone variety may be used when mixed with the sandstone, provided not over 10 per cent. of the mixture is calcium carbonate.

In the smaller cities, where it is not possible to secure vitrified brick or to purchase the equipment necessary for laying and repairing asphalt pavements, the asphalt block has been used. It has also been used in Washington, Baltimore and other of the larger Eastern cities. The manufacturers of asphalt block claim that it is superior to either the sheet or rock asphalt pavements, having the advantage of being quieter than the stone block, and less slippery than the sheet asphalt.

The methods of constructing brick pavements differ very little throughout the country. The bricks are usually laid on a concrete foundation, except where there is a natural gravel or sand subsoil. The concrete foundation should be covered with a cushion of sand $1\frac{1}{2}$ to 2 inches deep, and on this the brick should be laid. The joints should be grouted with asphalt or Portland cement, or filled with sand, depending upon conditions. If the traffic cannot be kept off the pavement long enough to allow the cement to set, it will be just as well to have the joints filled with

sand. In some of the smaller cities, where traffic is light and the natural foundation is sand and gravel, it is entirely unnecessary to construct a concrete foundation, and grouting the joints with cement only adds an unnecessary expense. A four or five-inch course of macadam is often equally satisfactory for foundation purposes as the same thickness of concrete. However, whether a concrete foundation is used or the joints grouted should depend entirely upon the location of the street and the traffic conditions.

In any case, none but the very best cement and brick should be used. The plan adopted by St. Louis to insure the use of the best materials is very satisfactory. I am opposed to setting up the product of any company as the standard of efficiency. No brick has ever yet been made but that some one has made a product which is better; and if Galesburg brick is made the standard to-day, to-morrow it may be necessary to specify some other "make" as the standard. Besides this, there are several grades of brick manufactured at every factory, in spite of the contention made by some companies that all of their brick is the same grade. If we should chance to obtain second or third-class brick from the factory which has been selected as the standard, the brick used might be of a very inferior quality. Therefore, I believe that the contractor should be free to procure his brick wherever he chooses, making them conform to the standard tests required by the city. The city, however, should make rigid specifications which will insure the use of the very best product manufactured.

The tests to determine the relative value of different kinds of paving brick vary considerably in different sections of the country. The most important of these, to the experienced observer, is perhaps that which is known as the absorption test; although the rattler test is considered to be most reliable by Orton, Wheeler and others who have given the subject much attention. When used in connection with other tests, it serves as an index of both the wearing quality and the strength of the brick. Specimens of the brick should be tested in the standard rattler, and determinations should also be made of the cross-breaking strength. A cross-breaking strength of less than 2000 pounds per square inch, or an absorption of more than 5 per cent., should exclude the brick from the pavement. The absorption test should be made after the brick have been broken and passed through the rattler. It is not sufficient that the samples of brick submitted to the engineer should conform to these specifications, but every brick which is used in the pavement should conform in quality to the samples submitted by the contractor.

I am convinced that brick pavement is admirably adapted for light business traffic streets. Brick pavement is not noiseless, as the brick manufacturer would sometimes have you believe, and for this reason it is not the most suitable pavement for residential streets.

I know very little about the construction of the new wooden block pavement. In Wisconsin our experience with wooden pavements has been with cedar block, which, as you know, has proven the most expensive pavement used in the Northern states. In Wisconsin this pavement usually consisted of 2-inch hemlock planks for a foundation and 6-inch blocks for the surface, without subsurface drainage. The blocks were cylindrical in shape, and, as a rule, the interspaces between them were filled with sand and gravel; occasionally with asphaltic cement. When first completed, the pavement was quiet, clean and altogether very satisfactory. The plank foundations, however, soon decayed, the blocks wore unevenly, and refuse and dirt accumulated in the joints, making the pavement not only unsanitary, but one of the most disagreeable to ride over.

The construction of the new wooden block pavements differs from the old cedar block in that rectangular instead of cylindrical blocks are used. The specifications call for greater care in the selection of the wood, while the pavement is laid on a concrete instead of a plank foundation. The block is now universally creosoted, and the joints between the blocks are filled with asphaltic cement.

Pavements of this character have proven very satisfactory in Canada and many of the European countries. I believe that this is one of three pavements which can be used to advantage on residential streets. This pavement is probably also suitable for light business traffic streets, and will probably supplant the brick pavement in many places. Should the demand increase rapidly for this kind of pavement, causing an increase in the price of the blocks, its use would probably be very much curtailed. We are everywhere limited in our purchases by the cost of things, and, even though this pavement may be one of the quietest for resident districts, it will not be considered if the expense of construction should very greatly exceed that of other pavements.

One of the most condemned of street pavements in St. Louis is that of the macadam, telford and novaculite type. St. Louis is not alone in its condemnation in this kind of pavement. Other cities have suffered from dust in dry weather and from mud in wet weather, and have paid dearly for their experience. On the other

hand, there are in the Northern and Eastern states cities that are loud in their praise of broken stone pavements. Massachusetts has constructed through her Highway Commission about 316 miles of macadam roadways. New Jersey has constructed over 550 miles of macadam. Newton, a suburb of Boston, is credited with having the finest boulevards of any city in the New England states. All of the pavements in Newton are macadam or telford.

One naturally asks why macadam streets should prove so desirable in one section of the country and so undesirable in another. This, I think, can be very easily explained. In the first place, macadam pavements should never be constructed in a city, town or village which has no provision for systematic maintenance. In the second place, macadam pavements, constructed of any other material than granite or trap rock, will prove expensive and often unsatisfactory. Limestone is mainly calcite or calcium carbonate, which has a hardness of 3 in a scale of hardness of 10, to which all minerals are referred. Granite and trap rock are composed of minerals which have a hardness of from 5 to 7. This difference in the hardness of the minerals composing the two rocks, combined with this texture, explains the vast difference in the wearing quality between limestone and granite or trap rock macadam.

There is absolutely no comparison between a road paved with granite macadam and one which is paved with limestone. If properly constructed and placed under a correct system of maintenance, a granite or trap rock macadam pavement is one of the most desirable for residential streets. It not only proves satisfactory to the residents, but is also the pleasantest over which one can drive, approaching nearest to the ideal dirt road. The dust and mud which accompany limestone macadam are not known on macadam streets constructed of trap or granite rock.

However, if a municipality is constructing pavements without a systematic plan of maintenance, I would never recommend the construction or use of macadam. A macadam pavement, if it is to be economical and satisfactory, must *"be kept up"* and not "repaired." Macadam streets should be kept up in the same manner as the road beds of our railroads. The streets should be divided into sections, and each section should be given in charge of a foreman, whose duty it is to keep his section of the street in repair. A section boss or foreman should not be given a street which is worn out, with instructions to keep that in repair, but he should be assigned to a newly paved street. With a moderate expenditure of money, it is possible to keep a granite macadam pavement in excellent condition.

Highways should be considered both vertically and horizontally. Vertically, we must consider the subsurface drainage, the subgrade, the foundation and superstructure. Horizontally, we must consider the pavement, the curb and gutter, the park area (or grass plot between the curb and the sidewalk) and the sidewalk.

In what has preceded I have attempted to express in brief my views on the construction of pavements, without reference to curb and gutter, park areas or sidewalk. Neither have I considered the width or crown of the street or the method of joining the pavement with the curb and gutter,—all of which are questions that present themselves to one who is discussing the problem of highway construction. The width of the pavement will depend entirely upon the amount and character of the traffic. In business sections of the city, the curb and gutter should be in contact with the sidewalk on one side and with the street pavement on the other. No attempt should be made to park a street in the business section unless the street is exceptionally wide. The condition of the traffic in the resident portions of the city, however, should be different, and the highway can ordinarily be divided in such a manner as to accommodate the traffic and still reserve sufficient space to permit of parking. In residence districts as much attention should be given to beautifying the highway as is given in the business sections to constructing durable pavements. The highway should be sufficiently broad to permit from 10 to 15 feet for park area on each side of the pavement between the sidewalk and the curb. This park area should be well sodded and planted with shade trees. Wherever possible, telephone and telegraph poles should be removed, and the wires placed either underground or in the alleys. The sidewalks should be constructed of cement, brick or flagstone, according to specifications provided by the city.

Not excepting even the stepping blocks and hitching posts, no wood should be used in the different forms of construction connected with a residence street which has been paved.

The streets of a city—by this I mean the sidewalks, the curb and gutter, the park areas and the pavement—should be under the direct control and supervision of the street superintendent. He should be supplied with assistants in the shape of foremen and laborers, whose duty it should be to keep up the public thoroughfares.

I appreciate very keenly the practical difficulties which would be encountered in attempting to administer the affairs of a great

city like St. Louis along these lines. I appreciate that those supposed to be in authority sometimes know what ought to be done, and yet have no power to do it.

Our municipal, as well as our state government, is too largely controlled by party politics. A man is seldom chosen for an important position in the administration of public affairs unless he is closely connected with the interests of either of the two great parties. After the election, the administration of the affairs of the city often becomes not so much a duty to the public as a duty to the party. Before any duty is performed or any policy pronounced, it must first be submitted to the party leaders, to determine whether or not it will have the right political effect. So keenly does the officeholder sometimes feel his obligations to the party that he sacrifices the public good for the party welfare. The good citizen of every community longs for the time when the administration of municipal affairs can be separated from political parties which have their birth in national principles; yet he knows that he is longing in vain.

There is no greater danger menacing the municipality to-day than that which is known as the party lash, which whips men into line without regard to the public welfare. The ambitious man, seeking political fame and national honors, instructs his subordinates to keep the men in line. There are larger interests at stake than the proper administration of the municipal affairs; the national party must be preserved.

We cannot deny the simple truth that three-fourths of the evils of our present municipal government are the direct result of our party system. It is the price which we pay for being conscious "that all men are created equal and are entitled to the inalienable rights of life, liberty and the pursuit of happiness," and our ancestors might have added "the right to a merchandise vote, subject to purchase or sale."

These are a few of the conditions which have confronted, and which confront to-day, the street commissioner and city engineer who seek to provide for the municipality those pavements which science and experience have demonstrated to be the best adapted to the varied conditions of a great city like St. Louis. The two greatest problems, connected with street paving and confronting us to-day, are (1) an equitable distribution of the burden of taxation incurred through the construction of street pavements; (2) a proper administration of the moneys collected for this purpose. If you can adjust these two problems, the cities will have very

little difficulty in securing the pavements best fitted for the various conditions existing in a metropolitan city.

The railroads have solved the problem of rapid transportation, and are now giving attention to the task of reducing to a minimum the noise and dust which formerly were given scarcely passing attention.

The noise of the street is being decreased on one hand by changes in the construction of vehicles and by new methods of shoeing horses. On the other hand, an attempt is being made to construct pavements which are clean and quiet.

I look forward to a time when we shall enjoy smooth, quiet and clean pavements; when steam, gas or electricity will supply the power now furnished by the horse and mule, and when the beast of burden will be driven only for pleasure. I look forward to a time when the continent will be provided with national highways—broad, smoothly paved avenues—over which a man may take his produce to market fifty miles distant and return the same day.

Not until this time has come can we consider our civilization equal in advancement to that of the Roman empire, whose pavements have endured until the present day.

## LIQUID FUEL—ITS APPLICATION, PAST AND PRESENT.

By R. G. Paddock.

[Read before the Technical Society of the Pacific Coast, March 7, 1900.*]

The discovery, within the past few years, of large quantities of petroleum in Borneo, California and Texas, and the probability of there being deposits of commercial importance in other places as yet but little known, has caused a marked revival of interest in the subject of liquid fuel, not only in the United States, but also abroad, where the question of future fuel supply has in recent years been the subject of much discussion. The assurance of a large output of cheap fuel from places geographically located, as are those mentioned, is of great economic importance.

When it is understood that nearly all industrial processes requiring coal or wood for producing heat may be performed equally well or better by the substitution of crude petroleum or some one of the distillates, the possibilities open to the Southern States and to California become apparent.

However great the demands may be for manufacturing purposes, a far greater amount will be required for railway and water transportation. Already tank stations have been established on the Suez Canal and at other points on the Eastern route, the price of oil per ton being about $12 at Suez, $7 at Hong Kong and $7.50 at Shanghai.

Tank steamers are also delivering oil at Cape Town for use on the South African railways.

The uses to which the various distillates of petroleum are applied are in general well known and need not be mentioned, except in connection with special furnaces to be described later. It is the crude oils and residuums, and the methods employed in their utilization for producing heat, that is of interest at this time.

The first scientific application of oil to boiler and other furnaces was in the United States in 1861 or 1862, and during the following twenty years innumerable experiments were made in this country and Europe.

The subject was studied by engineers of prominence, and by commissions appointed by several governments. Many forms of gasifying, vaporizing and spraying devices were tried and results obtained that are not exceeded in present practice. The object of this paper is not, therefore, to announce new discoveries or to offer new theories, but to give an outline of the more important features

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pertaining to old and new methods, which may be of interest to many who are but slightly familiar with the subject. The choice of solid, liquid or gaseous fuel is, in general, governed by their relative prices. Russian oils yield on distillation a large percentage of residuum, which can be obtained at a less cost than coals; hence, in Southeastern Russia and contiguous territory the waste product from refineries has been the main fuel for many years. In America the eastern oils can be, and usually are, so treated that little refuse remains; and, as coals are low in price, the use of crude or fuel oil has been restricted. California, Texas and Borneo oils are inferior to those of the East and of Russia for refining purposes, and are therefore likely to be used more generally in their crude state.

Oils vary considerably in their elementary composition and greatly in the forms in which the carbon and hydrogen are combined. Two oils of the same theoretical heat value may therefore give different results when burned with the same apparatus and furnace. The gravity, viscosity, mean boiling point and the temperature at which fractions are given off can be studied with profit by the engineer as well as by the refiner.

The following figures gathered from various tests show approximately the characteristics of Texas and Borneo fuel oils:

| | Texas. | Borneo. |
|---|---|---|
| Gravity | 25°- 30° B. | 32° B. |
| Flash point | 135°-150° F. | 200°-220° F. |
| Mean boiling point | 170°-190° F. | 390°-410° F. |
| Thermal values deduced from analysis and calorimeter tests | 18,500-19,000 B. T. U. | 18,800-19,000 B. T. U. |

California oils generally used for fuel do not average above 16° B. Samples of this gravity tested flashed at 275° to 300° F. and had a mean boiling point above 500° F. From a series of analysis and determinations with the Berthelot Calorimeter, Professor O'Neill, of the University of California, has found these heavy oils to contain 18,300 to 18,800 B. T. U. Much of the published data regarding our oils is inaccurate, and it is to be hoped that the results of Professor O'Neill's work will be made public. The oils of Texas and California contain more or less sulphur, sometimes as high as 3 per cent.; usually it is half this amount, or about the same per unit of weight as the average Pennsylvania coals; but the injurious effects upon a boiler will be nearly one-half less, owing to the heat ratio of the fuels. The great viscosity and high-boiling point of the California oil lowers its efficiency when com-

pared with lighter oils of the same theoretical value, as more heat must be expended in pumping, heating and spraying, and in reaching the initial temperature of combustion in the furnace.

Eastern and Russian oils have a value of 19,000 to 20,000 B. T. U. and sometimes reach 21,000; the latter figure being often given by technical writers. As an average it is too high. Calorimeter determinations of fuel values are the most satisfactory to the engineer, and the most accurate form of instrument that can be used by a person of ordinary skill is that devised by Professor R. C. Carpenter.

### METHODS OF APPLICATION.

The conversion of oil into gas before combustion seemed to the early inventor an ideal method, and hence, the first patents covered this form of application, and were granted to Shaw & Linnton, in America, in 1861 or 1862. A series of retorts was placed in the furnace; the oil entered at the top, and in its descent parted with the more volatile elements, while the residue was consumed in a corrugated receptacle at the bottom. Evaporation in a locomotive boiler about 11 pounds. Foote's furnace consisted of a cast iron retort in which the oil was evaporated, the gas issuing from small burners at the top. After the retort became heated, compressed air and superheated steam were introduced, causing the gas to burn with a clear blue flame. An evaporation of 21 5-10 pounds was claimed, but is undoubtedly an exaggeration.

Dorest & Blyth in England produced the gas in a separate retort and conducted it into the furnace by means of pipes having numerous small openings for its escape. Evaporation about 12 pounds. The system was also used in furnaces for heating armor plates, giving a ratio compared with coal of 1 : 2.25.

These various arrangements suffered rapid deterioration, and the pipes and passages filled with tar or coke. Later, in 1886, Thwaite claimed great success with his method, which consisted of injecting oil and steam into a retort placed in the furnace. The mixtures circulated through passages in the retort, and issued from an annular opening, where it was met by an air blast and projected forward, inclosing the retort which was thus kept at a high temperature. Mr. Thwaite claimed that the passage remained free from deposit, but recent trials of this device in England show that the pipes soon become stopped. From 1864 to 1880 experiments were tried with various forms of hollow grate bars, steps and oozing furnaces, the latter consisting of a layer of porous or broken material through which the oil was forced

from beneath. This secured an even flame, and 14 pounds evaporation was obtained.

We may now consider some of the forms of spraying devices. The first and simplest was a pipe, flattened at the end, through which the steam passed, and above this another pipe from which oil fell on the jet of steam. In Russia this was improved upon by Lenz, Artemeiv, Karapetov and others, by inclosing the oil and steam in one case, terminating in a long, narrow slit, through which the oil and steam were blown. Karapetov also allowed air to be sucked into the burner and mingle with the steam and oil at the nozzle; the arrangement being about the same as that now used by one of our railways. To obtain a fan-shape flame the burners of Artemeiv and Lenz were given a cylindrical shape at the nozzle, and slit horizontally. Since 1884 these flat-slit burners have been little used owing to their high steam consumption and inefficient atomization.

From 1863 to 1870 many experiments were made in England with different forms of sprayers and furnace linings. The former were sometimes concentric pipes; but often had the form of nozzles or orifices, through which steam was blown and the oil projected from above at various angles. The two were sometimes combined in a mixing pipe. The results claimed by some of these experimenters and by Admiral Selwin in particular, are extraordinary and have been often commented upon by compilers of technical works, some of whom have evolved far-fetched theories to account for an evaporation twice that theoretically possible. It is safe to say this miracle never occurred. The statements have been discredited by engineers who were familiar with the facts, and by those who have repeated the experiments with the same appliances. We are not warranted in believing that an evaporation of more than 18 pounds was ever obtained. However, credit must be given for the successful construction of spraying devices, for they have served as models for many of the forms that have since given best results. These forms have been generally of a concentric type, but varying greatly in detail. When well proportioned it does not seem to make any difference whether the steam is passed through the inner or outer pipe.

To give a wide-spreading flame for cylindrical furnaces the nozzle was sometimes given a conical shape, and a second cone was placed in front, so that, by adjusting the opening, the flame could be regulated.

From 1883 to 1886 the French Admiralty conducted trials with marine and locomotive boilers, using different atomizers, and both air and steam.

The former was unsatisfactory with pressure under 20 pounds. Heating the air was found to improve the evaporation ½ pound. The amount of air used in spraying equaled 5 per cent. of the steam generated, while 3½ per cent. was sufficient when steam was employed. The highest evaporation was 15 pounds.

In 1874 Urquhart began using oil residuums in Russian locomotives, and the results later attained by him have not been surpassed. The oil flowed from the tank by gravity. The sprayer was concentric, steam being conveyed by the inner tube. His success was largely due to the skillful arrangement of fire brick in the furnace, by which a part of the air for combustion was warmed and the spray thoroughly pulverized.

An evaporation of 12¼ pounds was the average performance of about 150 locomotives during a period of ten years. In America oil has been but little used in locomotives until its recent adoption in California. A number of arrangements have, however, been tried from time to time. The first sprayer was used in 1863 and was concentric in form. The oil tank was kept under pressure, causing the oil to flow with considerable force from the inner nozzle, where it was atomized by a jet of air.

The most satisfactory test, of which there is record, was made in 1888 by a board appointed by the United States Navy Department. In this instance both superheated steam and hot air were used. The burner consisted of an iron box placed in the furnace-door opening, and having a number of small holes through which the vapor escaped. Before reaching the burner the oil, air and steam were combined in a mixing chamber, resulting in vaporization. The oil used was 40° B. Flash point 64° F. Heat value estimated from analysis 21,000 B. T. U., or a theoretical evaporation of 21.7 pounds from and at 212° F. Moisture in steam 7.3 per cent. Water evaporated 17.9 pounds: to dry steam 16.9 pounds. Per cent. of total heat utilized 77.8. It will be noticed that the oil was above the average in quality and easily vaporized. Steam used in vaporization was not measured. Allowance for this would reduce net evaporation to at least 16.5 pounds. The foregoing is sufficient to illustrate the general practice to 1888 or 1890. Scotch, galloway and locomotive boilers were most often used in the tests mentioned. Furnaces were lined in various ways with refractory material, and gravity feed with light pressure was more common than direct pumping.

Since 1890 many forms of sprayers have appeared and some improvements been introduced in feeding and furnace arrangements. Only a few of the best systems, as yet but little known here, can be mentioned in the time at my disposal.

The use of oil in steamship furnaces requires a more careful treatment than is usually necessary on land. The location and arrangement of tanks must be carefully considered, and provisions made for the expansion of oil; co-efficients may be found in works on petroleum.

The settling of water, which always accompanies crude oil, is another important matter. Considerable trouble has occurred where this was not attended to, and numerous explosions were traced to this cause, particularly when one burner was used with air or steam without superheat.

Within the past two years about fifteen steamers of 4000 to 10,000 tons have been fitted in England with either the Flannery-Boyd or the Orde systems, the latter patents being owned by Sir Wm. Armstrong, Whitworth & Co.

The former employs two settling tanks, placed in the "between decks" and fitted with steam coils. The water is being precipitated in one, while the other is connected to the burners. The oil flows to the latter by gravity and passes through the outer tube of the small concentric burners, two of which are used to each furnace. The grates are not removed and are covered with broken brick. This arrangement is employed on account of its permitting a quick change to coal if necessary. The system is very simple, but the efficiency is less than with the Orde system, which probably gives a higher average than any that has proved commercially successful. In this system the oil is passed through a settling tank provided with an overflow pipe, from which it is pumped to the burners under pressure of 60 pounds. Before reaching the burners it is heated to a temperature just below the boiling point. On emerging from the inner tube of the burner it is met by steam and air heated to 600° F., or more if needed, and converted into a vapor. The greater part of the heat required for the operation is obtained from the waste gases. Two small burners supported on trunnions are used for each furnace. With Borneo oil of 18,800 B. T. U. an evaporation of 16 pounds has been obtained. A typical analysis of the waste gases shows:

| | |
|---|---|
| $Co^2$ | 13.20 |
| O | 3.60 |
| Co | 0.00 |
| HC gases | 0.00 |
| H | 0.00 |
| N | 83.20 |
| | 100.00 |

The largest steamer now fitted with this system is over 9000 tons register. Mr. Orde informs me that on one of the smaller steamers in the Eastern trade, using Russian residuum, the mean results of five voyages show an average of 15½ pounds evaporation.

One of the large Hamburg-American liners on the China route has recently been fitted with the Korting mechanical sprayers. This is a type practically unknown in America, although several thousand are used in Europe. Their operation is simple and they are noiseless. The furnace must be well lined with brick in order to maintain the temperature. An evaporation of 12.5 pounds is said to be about the limit, although a possible 14 pounds is claimed by some. As perfected by the Kortings, one of the best-known engineering firms in Europe, the apparatus consists in general of a pump, two heaters and a burner. The oil under 60 pounds pressure is first heated by the pump exhaust, and then by the steam at boiler temperature, in order to thin it as much as possible. On entering the burner it is given a peripherical motion, and on its discharge from the nozzle, which is the apex of a cone, the centrifugal velocity is sufficient to pulverize it into a fine spray. For small plants without an auxiliary boiler a hand pump is provided, so that by heating the oil with a torch or otherwise, or by using a thin oil, fire can be started when no steam is carried. A modification of the Korting system, invented by Mr. R. A. Meyer, of Batavia, Java, has been applied to several steamers of the Dutch line, of which he is superintendent. Each furnace front is fitted with a cylindrical extension, the periphery of which contains a series of iron ducts, wound spirally, through which all the air passes, and is heated to a considerable degree by the flame which traverses the interior of the cylinder.

The Italian government has experimented with oil on war vessels, both alone and in combination with coal. Used with the latter, it affords a means of rapidly firing boilers in an emergency and of securing a greater output of steam. Had our own navy been thus equipped, there would have been less trouble in the Cuban blockade. A given weight of oil occupies less space than a like amount of coal, and it can be stored in places that are usually unavailable for other purposes. With suitable pumping arrangements it can be loaded very rapidly and without dirt. The use of oil, by reason of this saving in bunker space together with the difference in heat values, doubles the steaming radius of a vessel. The use of air for spraying, once thought essential in Marine practice, is being abandoned for steam, which is less trying to the boilers and probably more economical. Most vessels are now fitted

for distilling water, and it has been found cheaper to operate the still than the air compressor.

Next in point of interest are Metallurgical furnaces. The Eams and other processes were employed in America at an early period in reverberatory furnaces and were entirely successful. Vaporization by superheated steam was a favorite method. Later, in Russia, heating and scrap furnaces, designed for coal, were fitted with an iron plate, over which the oil flowed, where it was met by an air blast and projected against a low bridge wall. A few favorably situated plants in Pennsylvania, among whom may be mentioned the Pennsylvania Steel Company, have for some years used oil in various furnaces for reheating, etc., and until recently the above company has used it for open hearth steel.

The particular arrangements used were devised by Mr. Campbell, the superintendent, well known as an authority on structural steel. Mr. Campbell assures me that for all the operations mentioned he has found oil to be entirely satisfactory.

For processes requiring high temperatures the air should be heated by the waste gases. For lower temperatures cold air may be used, and the waste heat utilized under the boilers, the same as is done with coal or gas. All petroleum oils burn with a long flame, and like flame from producer gas it is subject to chilling, and possible extinguishment if, in the first stages of combustion, it passes through wide air spaces or comes in contact with rapid conductors of heat, such as iron.

While this effect is more noticeable in boiler furnaces, still, to achieve best results, Metallurgical furnaces must be carefully designed, having in view the work to be performed. Some very fine specimens of furnaces for flue welding, tempering and general forging are manufactured by Eastern firms and used quite extensively in railroad and other shops. They are symmetrical in appearance, encased in cast iron or steel and lined with an extra quality of fire brick. The oil is first injected into a combustion chamber by air at one or two pounds pressure, and being ignited passes to the furnace proper, additional air being supplied at suitable points. A difference of opinion has existed as to the merits of high and low air pressures. Where direct firing is used, and the oil is viscid, higher pressures are desirable. With combustion chambers pressures of one to two pounds are doubtless more economical. For welding, especially with direct firing, the air should be dry, otherwise excessive scaling will occur. Ordinary steam spraying is unsuited to this work, first, because the dissociation of the oxygen and hydrogen of steam in contact with iron at a red heat appears

to produce the former in a nascent state, causing a more rapid oxidation than when liberated from the nitrogen of air; second, by reason of the cooling action mentioned; combustion of the steam and oil vapor cannot be effected at a rate sufficiently rapid to produce the high temperature required. However, if superheated steam be employed, and the oil vaporized, iron may be readily melted. Air spraying being the simpler method, is usually employed. Except for large furnaces, air pressures under one pound are seldom satisfactory, as it is insufficient to produce more than a coarse spray with other than very thin oils. The ratio of efficiency compared with coal is greater in this class of work than in steam production. In large furnaces, fitted with regenerative chambers, 800 pounds to 1000 pounds of oil will perform the work that requires 2000 pounds of good coal. In smaller furnaces for forging, welding, tempering, etc., the heating ratio is not less than 1 : 2, but the saving made may be much greater than this implies. With oil a better quality of work is produced on account of a clean fire and uniform heat, and from 50 per cent. to 200 per cent. increase can be made in the output. It is doubtful if our heavy oils will prove entirely satisfactory in small furnace work, but light gravity oils or distillates at three cents per gallon should be 50 per cent. to 60 per cent. cheaper than coke, anthracite or Cumberland coal at present prices. It is somewhat strange that our iron founders should continue to use coke at $12 per ton, when oil can be had for 70 cents or 80 cents per barrel. Whether open hearth steel can be produced here in competition with the East depends largely upon the price of scrap and pig iron if present processes are employed. No method has been found by which iron ores can be reduced to pig with oil fuel alone, as it does not afford the necessary carbon and carbon monoxide in an available form, but it may be possible to use it in a direct steel process. The subject of iron and steel making is one of importance to the Pacific Coast, but is beyond the limits of this paper. For ores other than iron, oil may be used for most operations of reducing and refining, and it is employed to a considerable extent in this State for these purposes. In the manufacture of soda ash and glass it is a superior fuel. The cost of the former has been reduced, and the quality of the product improved, by substituting a furnace designed especially for oil in place of the old style reverberatory. Before passing to another subject, mention should be made of a class of furnaces manufactured by the American Gas Furnace Company. For the finer classes of work crude oil is unsuited, natural or artificial gas being employed. The above company

use a gas made from naphtha. A uniform heat can be maintained, which is particularly desirable in operations upon fine steel. Quite often the operations of annealing, tempering and bluing are accomplished automatically. Many of these furnaces are used in the manufacture of bicycles, tools, dental goods, cutlery, etc. It is estimated that $2\frac{1}{2}$ gallons of 76° naphtha will mix with air at a certain temperature to form 1000 cubic feet of gas, containing 306,365 B. T. U. Twenty-two hundred cubic feet of this gas equals 1000 feet of 20-candle-power coal gas.

It is manifestly impossible to fix any definite ratio between oils and coals. The one may have a value of 18,000 to 20,000 B. T. U., and the other is still more variable. Conditions of use also vary widely. Assuming an average value of 19,000 units for oil, a ratio of 1 : 1.6 to 1 : 1.9 will be a fair comparison with American coals for steam generating, the latter figure applying to some of the Western lignites. The subject has been treated at length by Professor Denton, of Stevens Institute of Technology, in reporting upon a recent test of Texas oil, which may be found in the February number of *Power*. A brief summary of the estimates given is as follows:

On the basis of 10 square feet heating surface per boiler horse power.

| | |
|---|---|
| Western coals wet (*i.e.* 3 per cent. water) average evaporation, lbs.... | 7.50 |
| Texas oil, average evaporation, lbs. .................................. | 14.80 |
| Ratio .................................................................... | 1.97 |
| Barrels of oil = 1 ton coal (2240 lbs.) .............................. | 3.54 |

*Comparative Value.*

| | |
|---|---|
| Oil at 70 cents per barrel = 2240 lbs. coal at ........................ | $2.50 |
| Oil at 85 cents per barrel = 2240 lbs. coal at ........................ | 3.00 |
| Oil at 99 cents per barrel = 2240 lbs. coal at ........................ | 3.50 |
| Oil at $1.13 per barrel = 2240 lbs coal at ............................ | 4.00 |
| Oil at $1.28 per barrel = 2240 lbs. coal at ........................... | 4.50 |

In applying these figures, it should be remembered that many plants using oil, at least on this coast, are not getting as high results as are given above.

The results of public tests and the opinions of leading engineers in this country and Europe show that, with spraying devices, using ordinary steam, an evaporation of 14 or $14\frac{1}{2}$ pounds is about the limit that can be attained in average work, and to reach this the burner must not use more than three or four per cent. of steam, the oil must be thin, and last, but most important, the furnace arrangement must be such that a high temperature can be maintained. To approach nearer the theoretical limit,

vaporization appears to be the most practicable plan. The latter method is mentioned most favorably by Professor Durand, of Cornell, in a recent book on marine engineering. Many persons suppose that if oil and steam at boiler temperature are sufficiently mixed in the burner, vaporization can be produced. Others suppose that by mixing the two in a pipe, which is heated in the furnace, they can obtain the desired results. In the first instance the steam merely loses heat, some of which is gained by the oil; in the latter, if the pipes are heated to redness, some parts of the oil will be vaporized, some will pass through as thick oil, and the rest remain in the form of coke. Some steam and oil vapor will unite, but a mixture of this kind, after being passed through 10 feet of pipe heated to a bright red, has been found to contain 20 per cent. aqueous vapor. If the pipe remains below a red heat, some of the lighter elements may be distilled, but the mixture is chiefly oil and water vapor. It should be understood that we are considering the action of the average crude oils, and that vaporization means the combining of the steam and oil, without a residue, in a gas sufficiently staple to enable it to reach the furnace without condensation. Superheated steam appears to be the only medium which will accomplish this. Its action is quite different from saturated steam, and its power of lowering the mean boiling point of oils is well known to refiners. The temperatures of oil and steam necessary to produce a vapor depends upon the characteristics of the oil. Thus, an arrangement suited to West Virginia oil of 40 per cent. B. might not, and probably would not, be sufficient for our heavy oils.

Elsewhere than in California, round-flame burners are generally employed. Two or more are, as a rule, used for each boiler or furnace. They possess the advantage of economy, better regulation can be secured, and there is less danger of explosions, as one may become stopped and the other remain in operation. With a single burner, and a load which varies considerably, there is usually more or less trouble. When the flame is greatly reduced it is apt to be fitful, and often white vapor is given off, which passes up the stack unconsumed. Its disagreeable odor can be perceived very often while traveling about the city. As to burners, there are a number of good ones in the market, adapted to different kinds of work, and some that are phenomenal in their capabilities, if all that is claimed for them be true. Too much importance is quite generally attached to the burner, and too little to the furnace. Quoting from a letter from an engineer who has designed some of the largest and best equipments in the United

States, "The oil atomizer is of secondary consideration. Furnace construction and the method of preparing the oil is everything." A common impression prevails that when oil is being burned without smoke it is doing all the work possible. Efficiency cannot be measured in this way.

Attempts at converting crude oil into fixed gas in small generators for manufacturing purposes have occasionally been made, but have not been successful financially; but the ease with which gas can be conveyed and applied makes its use desirable, especially in large shops, with many furnaces widely separated, and in particular cases the employment of light gravity Coalinga or a gas oil might be practicable.

If any complete boiler tests have been made here in the past two years, the writer has been unable to ascertain the facts, and it is by no means easy to get unbiased opinions from engineers in charge of plants. Several gentlemen connected with large power houses in this city state that from 12½ to 13 pounds is, in their opinion, an average evaporation. With furnaces that heat only by radiation, and with 12 to 17 inches between the flame and boiler, often occupied by an excess of cold air, the former is about all that can be expected. There are a few notable exceptions, where 14 pounds is probably averaged. In our locomotives it is doubtful if the average is 11 pounds, and this will, no doubt, be bettered. With the burners now used, steam consumption must be high, atomization imperfect, and too much cold air is permitted to surround the spray as it leaves the nozzle. When the engine is worked at all heavily, much of the vapor is not inflamed by the brickwork, but rises to the sides and crown sheet, becomes cooler, and is finally condensed to soot in the tubes, necessitating the frequent use of sand to keep them from choking. A better and more durable arrangement of furnace lining might be made if a different material was employed. There is in this State large quantities of substances suitable for the production of a basic brick possessing refractory qualities and tensile strength exceeding the best silica brick made in England. With these basic brick arches, etc., could be made lighter in weight, while gaining in strength. A large engine recently built for the Santa Fe Railway may be expected to give better results. The furnace consists of three corrugated tubes 28 inches by 86 inches, which terminate in a combustion chamber 40 inches long. The flue sheet forms the forward end of this chamber. Each of the furnace tubes is fitted with a burner, and has a lining and bridge, or baffle, of fire brick. The air-pump exhaust is used for heating the oil.

A review of three carefully conducted tests shows results as follows:

First. Vaporization system, Borneo oil, 32° B. theoretically possible from and at 212° F., 19.46 pounds. Highest net, 16 pounds.

Second. Vaporization system, West Virginia oil, 40° B. theoretical, 21.7 pounds. Net, 16.5.

Third. Steam spraying system, warm air for combustion, test by Professor Denton, Texas oil, 25° B. theoretical, 19.77 pounds. Highest net, 15.16 pounds. Assuming 18,600 B. T. U. as an average for California 16° B. oil, or a theoretical of 19.25 pounds, and considering the greater amount of heat lost in pumping, heating and spraying, a net evaporation of 14.8 pounds with spray systems and 15.7 pounds with vaporization is as much as can be hoped for, and to reach this in everyday work will require more careful design and construction than is usually seen. Almost any arrangement will suffice to burn oil and evaporate 12 or 12½ pounds in stationary boilers, and at the relative price of fuels on this coast this will effect a large saving. Power users have, therefore, not felt it necessary to invest money in efficiency tests.

I am aware that some deductions as to efficiencies are at variance with statements often heard, and shall be glad to be corrected, if wrong, by those having reliable data.

There is still much to be learned, and I venture the hope that the members of this Society may have no small part in future investigations leading to a better knowledge of liquid fuel.

## DISCUSSION.

The President, Mr. Henny.—It is a matter of great importance to the Pacific slope, and particularly to California, that we have here before us a cheap fuel, and it is to be hoped that the application of it in this form may be the beginning of an era of great industrial development in California. I hope that the members will contribute to the discussion of this paper.

A Member.—What is the value, or the effect, to be obtained from these oils and distillates when made into gas for use in heat engines or gas engines?

Mr. Paddock.—I am not prepared to say much on that subject. I have made no experiments myself with the so-called heat engines. Professor O'Neill, as near as I remember, found that distillates of 28 or 30 gravity contained about 19,100 or 19,200 B. T. U.

A Member.—Have any tests been made here, except the ones spoken of and those made by the American Sugar Refinery and the Union Iron Works some years ago?

Mr. Paddock.—The only one I have had access to is a paper read before this Society some years ago by Mr. Hunt, who is now manager of the Independent Electric Light Company. I think he used Ventura oil of about 25 gravity. He estimated that the average evaporation obtained was 14.2 pounds. Now, this oil is better than the Kern River oil, and it should evaporate more water. We have all been told that the Kern River oil will evaporate from 15 to 15.5 pounds, but in one of the power houses here, where the most efficient equipment is installed, the engineer in charge does not claim a higher average than 14 pounds.

Mr. Livermore.—The Kern River fields are supposed to be very large, but the uses of oil are increasing very rapidly. How long are these fields likely to last?

Mr. Paddock.—I have not given much attention to that particular subject. The oil district in Pennsylvania has been in operation since 1858, and the Russian fields almost as long. Many estimates have been made. I think you can get them at the State Mining Bureau, expressed in number of barrels per acre, etc. New districts are being discovered right along; for instance, in Java. The oil fields in Borneo have been operated for some time. There is a great deal of oil in India, and some in Japan. How much, we do not know. There are supposed to be extensive deposits in China and Siberia. In the former country native superstition and prejudice have prevented the development of these fields. The Texas gushers were originally scattered over a very small area, but I have not heard any estimates as to the permanency of that field. In fact, all these things are more or less guesswork. The Baku district, in Russia, that has produced such an immense amount of oil, embraces a very limited area.

Mr. Henny.—As to the saving which is effected in the handling of oil, I have been East recently, and have visited very large manufacturing plants, where great outlays had been made for mechanical stokers and devices for the handling of ashes, which, I think, would be more or less superfluous if oil were employed as a fuel. I have considered the cost of burning oil to be very much less than that of coal. We would like to have you tell us something of that feature.

Mr. Paddock.—In large plants or large steamships the saving effected would be very considerable, whereas in small plants it would not amount to much. In all plants there must be at least one

man whose duty it is to watch things. In small plants one engineer can attend to things in general. In very large plants, where oil is used, one or two men can attend to the work at a dozen furnaces. One man even can attend to the work at all furnaces, but for safety's sake it is well to have two men. It would be impossible to give any exact figures on that subject. The saving is very great, but, with the figures that I have given, the supposition is that the coal is laid down at the furnace, as well as the oil. The ratio then is about 1 : 1.6, or, in the case of good oil and poor coal, such as on this coast, the ratio is approximately 1 : 1.9, or as high as 1 : 2 even. With these figures the cost of hauling away the ashes is not included. In small plants, the difference of cost, as far as labor is concerned, is not very considerable, whereas in large plants it would amount to a great deal. One important point is that steamers can be loaded so much quicker. Three thousand tons of oil can be put in the tanks of a ship inside of three hours, and everything is very clean during the loading, without any disagreeable coal dust. I think it would be a great thing for our ocean-going vessels. However, the heavy California oil is very hard to handle, especially in cold weather. It is extremely hard to pump this oil.

MR. HENNY.—I understand that a lumber schooner at Pasadena has been burning oil for the last ten years. It has been done very successfully, and yet it has taken so many years before other schooners have commenced to adopt the same system. This, I understand, is largely due to the fact that the inspector of hulls has called attention to various points of danger, and, as I am told, has made very excessive demands, and that has been the reason why oil has not been more extensively introduced in the navigation of the coast. Now, however, a large number of schooners have been fitted with oil. We would like to hear whether the introduction of oil in navigation does introduce an element of danger?

MR. PADDOCK.—With oil such as we have in the East, Russia, and with light Texas oil, quite a large evaporation takes place, 8 to 10 per cent. within a week after it is pumped from the well, and these vapors are inflammable. In the districts where these oils are produced, numerous explosions have taken place, but are less frequent now the tanks are well ventilated. With heavy California oil there is practically no reason for apprehension on that score. As I stated, with 16° B. oil I cannot get a flash under 280° or 300° F. Even when a vessel passes the equator, the oil is not subjected to such a temperature. The trouble is of a different nature. The inspector of boilers, in a conversation I had with him the

other day on that subject, said his objection was that the companies owning these vessels might not employ a class of reliable and skillful stokers to attend to the furnaces. If the appliances are not such as to take the water out of the oil, or if the burner becomes stopped for a short period, and afterward begins to flow, the furnace, or rather the bricks of the furnace, may in the meantime have cooled to a temperature of 600° or 800°, in which case the gases might not be immediately ignited. A considerable amount of gas would be generated, which might later take fire and cause an explosion. Mr. Bulger said he had no objection to the use of oil on the vessels, but the companies must employ men who can attend to things properly. If the fireman does not attend to his business in plants where coal is used, the effect will be that the steam goes down, and the engineer can then make the stoker attend to his duty. With oil it is different. If the stoker does not attend to his business, an explosion may take place without any previous indication. I remember in one particular case, while visiting a large plant, I saw an immense amount of smoke going out of the stack. I went in and found the man in charge asleep. Of course, it is not safe to allow an oil plant to run itself under any circumstances.

## CONCRETE CONSTRUCTION.

FURTHER discussion, April 1, 1902, of paper by C. R. Neher, read before the Engineers' Society of Western New York, March 5, 1901, and published in the JOURNAL of April, 1901, Vol. XXVI, No. 4. See also JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, January, 1902, Vol. XXVIII, No. 1, p. 38.*

MR. RIPLEY.—I agree neither with the dry-mix men nor with those who would have an inch or two of water standing on the freshly rammed mass and the workmen wading around ankle deep.

Between the two there is a proper mean which can be obtained in actual practice by experienced oversight.

In the laboratory the ingredients can be dried, and the water measured and added portion for portion; but on construction this is seldom possible and rarely practical.

Mr. Neher spoke of the usual condition when he said, "Frequently we get wet and dry both on the same day from the boats, etc."

A sand or gravel pile, rained on to-night, will not require the same amount of water added for the mixing as it would to-day.

I have seen batches, made from the same piles of gravel and sand, vary from a moderately dry to a sloppy mess, when using equal amounts of water; because, in the former case, the ingredients happened to come from the tops of the piles, and in the latter from the bottoms of the piles where the frost was yet in evidence. (We were using hot water.)

No two piles of sand will absorb the same amount of moisture unless seasoned for a length of time according to climatic conditions.

Concrete, when too dry, sets in layers, and in extreme cases is granular and of no account, resembling concrete poor in cement.

Concrete too wet may float the cement; but the greatest loss is usually due to inability to handle it owing to its semifluid condition.

Rules for the proportions of ingredients may be put in small type; but TAMPING should be in capitals.

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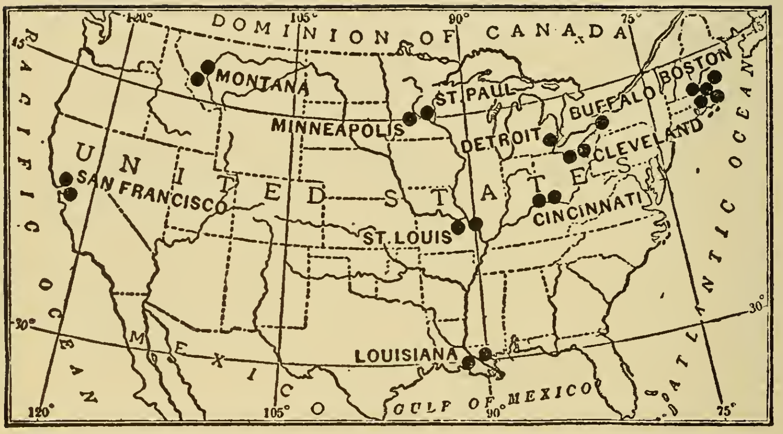
*Manuscript received April 17, 1902, Secretary, Ass'n of Eng. Socs.



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## THE DETERMINATION OF UNIT STRESSES IN THE GENERAL CASE OF FLEXURE.

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[Read before the Society, December 11, 1901.*]

### PREFATORY.

FLEXURE is usually met in practice in the simple special case in which the neutral axis is normal to the plane of the loads. The determination of unit stresses for this case is commonly treated in the standard works on resistance of materials, but the fact that this case is a special one is rarely pointed out, and other cases are usually ignored. The result is that methods valid for all cases are comparatively little known, and in default of such methods, the simple formula of the special case is applied, even in well-known text-books, to cases outside of its proper domain.

In order to call more general attention to methods by which the distribution of stress can be determined for any case of flexure in a straight bar (in which the elastic limit is not overstepped), the following paper has been prepared. Though the subject is no less important from the point of view of abstract science than from that of practice, special effort has been made in this paper, by means of fully worked numerical examples and otherwise, to meet the needs of practitioners.

Among the problems in which a knowledge of the general case is necessary may be mentioned the design of purlins of any kind on a sloping roof, the proportioning of unsymmetrical sections (such as angles and Z-bars) subject to any kind of transverse load, and the

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investigation of eccentrically loaded columns or ties, including such as are commonly used in riveted truss work. The numerical examples given herein illustrate some of these problems.

It will be observed that the mathematical knowledge required for dealing with the general case is no more advanced in kind than is needed for dealing with the simplest beam.

All results here given are strict mathematical deductions from the generally accepted hypothesis that the unit stress at any point in a moderately bent beam is proportional to the distance of that point from the fixed line called the neutral axis.

This paper subdivides naturally into four parts, viz:

I. Preliminaries regarding moments of inertia and products of inertia (Sections 1-7).

II. The development of the general formulas of the subject, and exposition of some important geometric properties of the neutral axis (Sections 8-11).

III. Algebraic applications to practical problems (Sections 12-13).

IV. Graphic applications to practical problems (Sections 14-29).

The attention of readers more interested in results than in their derivation and proof is directed specially to Parts III and IV, and particularly to the Kernel and Resistance Polygon Methods of Part IV. Reading Sections 12, 15*b,* 26-28 is recommended as perhaps the quickest way of getting a fair idea of the purport of the paper.

The writer takes much pleasure in acknowledging his indebtedness to Professor Müller-Breslau, of Berlin, whose admirable *Graphische Statik der Baukonstruktionen* has been his main resource in the study of this subject. The general lines of Müller-Breslau's work, as well as his notation, have to a large extent been retained. In addition to the places accompanied by page references to his book, Sections 8, 11, 13.I, 21 and 22 may be mentioned as following him with a special but varying degree of closeness.

Other notable sources of material have been the *Taschenbuch Hütte,* 17th edition, and the contributions of Professor Mohr, of Dresden, and Land, of Constantinople, to the German technical press, to which references are made in the proper places, and from which have been culled the points of most immediate practical application.

It is believed that equation (14), and the improved methods which it makes possible are here published for the first time.

The writer's personal thanks are due his colleague, Mr. J. A. Moyer, S.B., for suggestions and for assistance in many ways.

## PART I.

### MOMENTS OF INERTIA AND PRODUCTS OF INERTIA, AND THEIR DETERMINATION FOR ANY SET OF AXES.

1. *Moments of Inertia.—Products of Inertia.* In the theory of resistance of materials, the series of quantities which arise from summing, for any surface, the products of its infinitesimal component areas by the squares of their respective ordinates or abscissas,

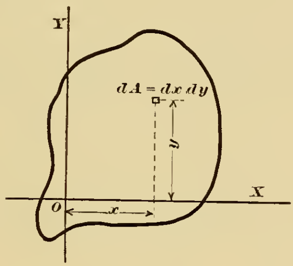


FIG. 1.

or by the products of their co-ordinates, are called respectively the moments of inertia and product of inertia for the surface for the given pair of axes. These two moments of inertia and the product of inertia can accordingly be written and named for any figure, as that of Fig. 1, as follows:

$I_x = \iint y^2 dxdy$, or moment of inertia referred to the axis of X;

$I_y = \iint x^2 dxdy$, or moment of inertia referred to the axis of Y;

$Z_{xy} = \iint xydxdy$, or product of inertia referred to axes of X and Y.

Moments of inertia are always positive. Products of inertia are positive or negative, according as the preponderance of the section is in the first and third quadrants or in the second and fourth.

Evidently if either axis of co-ordinates is an axis of symmetry, $Z_{xy}$ will be zero, for then, for every $-$ x y dxdy, there will be a corresponding $+$ x y dxdy to neutralize it.

It will be found convenient to express each of these quantities in terms of the area, A, of the section and the product of two selected lengths. In the case of moments of inertia, there is taken for this product the square of a length spoken of as the radius of gyration, and written r. The product of inertia must, as a conse-

quence of its being variable in sign, be written in terms of two separate lengths. For one of these we shall take a convenient radius of gyration, a quantity always positive, and for the other an additional length of varying sign.

The expressions then take the form

$$\left.\begin{aligned} I_x &= A\ r_x^2 \\ I_y &= A\ r_y^2 \\ Z_{xy} &= A\ c_x\ r_x \text{ or } A\ c_y\ r_y \end{aligned}\right\} \quad \ldots\ldots\ldots \quad 1)$$

where $r_x$ and $r_y$ are radii of gyration referred to OX and OY respectively, and $c_x$ and $c_y$ are lengths which may be called the "product abscissa" and "product ordinate" respectively.

For convenience throughout the following work, the convention will be adopted that the one of the two axes for which I is the larger (if any difference there be) shall be taken as OX and the other as OY,—*i.e.,* that $I_x$ shall always be as great as or greater than $I_y$.

2. *Parallel Transference of Axes.* Required the section moments of the second degree for axes O′ X′ and O′ Y′ in terms of

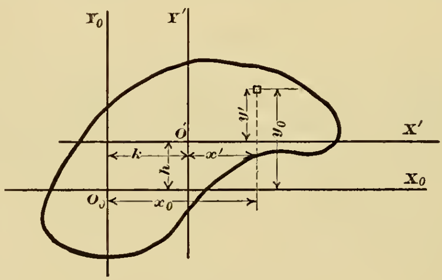


FIG. 2.

the values for a parallel set of axes, $O_0\ X_0$ and $O_0Y_0$, calling the co-ordinates of O′ (referred to $O_0$) k and h, and identifying various values by the suffixes of the corresponding axes (Fig. 2), and bearing in mind that $\iint y_0^2\ dxdy = I_{x_0}$, $\iint x_0^2\ dxdy = I_{y_0}$, $\iint x_0y_0\ dxdy = Z\ x_0y_0$, and $\iint dxdy = A$, we can write at once:

$$\left.\begin{aligned} I'_x &= \iint y'^2\ dxdy = \iint (y_0 - h)^2\ dxdy \\ &= I_{x_0} - 2\,h \iint y_0\ dxdy + A\ h^2 \\ I'_y &= \iint x'^2\ dxdy = \iint (x_0 - k)^2\ dxdy \\ &= I_{y_0} - 2\,k \iint x_0\ dxdy + A\ k^2 \\ Z'_{xy} &= \iint x'y'\ dxdy = \iint (y_0 - h)\ (x_0 - k)\ dxdy \\ &= Z_{x_0y_0} - h \iint x_0\ dxdy - k \iint y_0\ dxdy + A\ h\ k\,. \end{aligned}\right\} \quad 2)$$

But the only case of common occurrence in practice is that in which $O_0$ is at center of gravity of the figure. For this special case both $\iint y_0 \, dxdy$ and $\iint x_0 \, dxdy$ vanish and we can write:

$$\left.\begin{aligned} I'_x &= I_{x_0} + A h^2 \\ I'_y &= I_{y_0} + A k^2 \\ Z_{xy} &= Z_{x_0 y_0} + A k h \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad 2a)$$

where $I_{x_0}$, $I_{y_0}$ and $Z_{x_0 y_0}$ are section moments of the second degree referred to center of gravity axes.

*3. Rotation of Axes About Fixed Origin.* Suppose the rectangular axes OX, OY (Fig. 3) be revolved through the angle $\alpha$ to the position OX′, OY′; required the values $I'_x$, $I'_y$ and $Z'_{xy}$ in terms of $I_x$, $I_y$ and $Z_{xy}$.

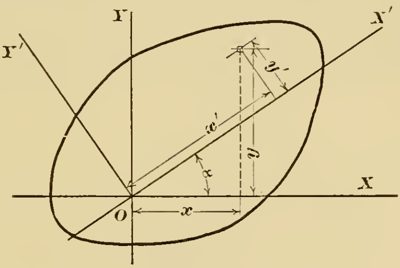


FIG. 3.

Since $x' = x \cos \alpha + y \sin \alpha$ and $y' = y \cos \alpha - x \sin \alpha$

$I'_x = \iint y'^2 \, dxdy = \iint (y \cos \alpha - x \sin \alpha)^2 \, dxdy$

$I'_y = \iint x'^2 \, dxdy = \int (x \cos \alpha + y \sin \alpha)^2 \, dxdy$

$Z'_{xy} = \iint x'y' \, dxdy = \int (x \cos \alpha + y \sin \alpha)\,(y \cos \alpha - x \sin \alpha) \, dxdy$

Bearing in mind that $\iint y^2 \, dxdy = I_x$, $\iint x^2 \, dxdy = I_y$ and $\iint x\, y \, dxdy = Z_{xy}$, the foregoing will be found to reduce to

$$\left.\begin{aligned} I'_x &= I_x \cos^2 \alpha + I_y \sin^2 \alpha - Z_{xy} \sin 2\alpha \\ I'_y &= I_x \sin^2 \alpha + I_y \cos^2 \alpha + Z_{xy} \sin 2\alpha \\ Z'_{xy} &= \tfrac{1}{2} (I_x - I_y) \sin 2\alpha + Z_{xy} \cos 2\alpha \end{aligned}\right\} \quad \ldots\ldots \quad 3)$$

By use of equations (2) and (3), section moments of the second degree being known for one pair of axes, they can be found for any other pair.

*Corollary.* If the special value of $I'_x$ for an axis inclined by 45° to OX be called $I_z$, then by insertion of $\alpha = 45°$ in the first equation of (3), it appears that

$$I_z = \tfrac{1}{2} (I_x + I_y) - Z_{xy}$$

or

$$Z_{xy} = \tfrac{1}{2} (I_x + I_y) - I_z \quad \ldots\ldots\ldots \quad (3a)$$

an equation which, for some figures, affords a convenient means for calculating $Z_{xy}$.

*Corollary.* By adding together the first two equations of (3), there appears the important fact that

$$I'_x + I'_y = I_x + I_y \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 4)$$

that is, for any section, so long as the origin is unchanged, the sum of the moments of inertia for any pair of rectangular axes is a constant.

*4. Graphical Solutions of Equations (3).* Given $I_x$, $I_y$, $Z_{xy}$ and $\alpha$; required $I'_x$, $I'_y$ and $Z'_{xy}$.

*I. Müller-Breslau's Solution.** From any point, as O (Fig. 4), parallel to (or, as in Fig. 4, along) the axis of X, lay off to scale O $I_x$ to represent $I_x$† and O $I_y$ and $I_x$ O′ each to represent $I_y$. At $I_y$ to same scale, set up an ordinate ending at A to represent $Z_{xy}$.

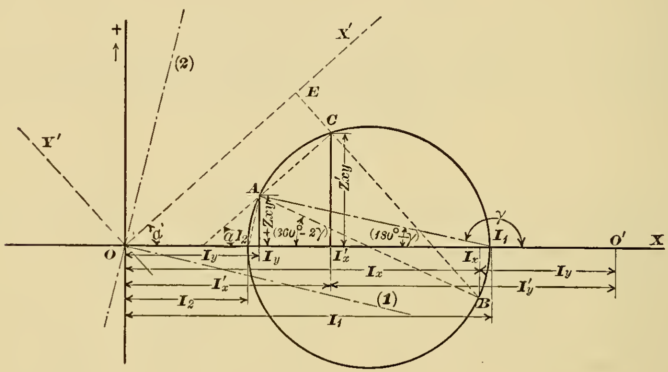


FIG. 4.

These three measurements to be laid off with strict regard to sign,—*i.e.*, according to usual convention, $I_x$ and $I_y$ will be laid off toward the right, and $Z_{xy}$ upward or downward, according as it is positive or negative.

At $I_x$ set up an ordinate numerically equal to $Z_{xy}$, but of opposite sign to $Z_{xy}$, ending at B. On AB as diameter, describe a circle. Through A draw parallel to OX′, intersecting circle a second time at C. The foot of a perpendicular from C upon OO′ will be a point $I'_x$, such that $OI'_x$, $I'_xO'$ and $I'_xC$ will represent $I'_x$,

*Müller-Breslau: Graphische Statik der Baukonstruktionen, I, pp. 37, 38.
†Bearing in mind convention of Section 2.

$I'_y$ and $Z'_{xy}$ respectively*,— $Z'_{xy}$ being positive or negative according as C is above or below OO′.

*II. Mohr-Land Solution.*† From O (Fig. 5), the origin of two rectangular axes, OX and OY, having respectively the same directions as the axes to which the figure is referred, lay off, along OY, OC and CD representing to scale $I_x$ and $I_y$ respectively. To the same scale lay off CT parallel to OX to represent $Z_{xy}$,—to the right or left according as $Z_{xy}$ is positive or negative. On OD as a diameter describe a circle calling its center M. Through O draw

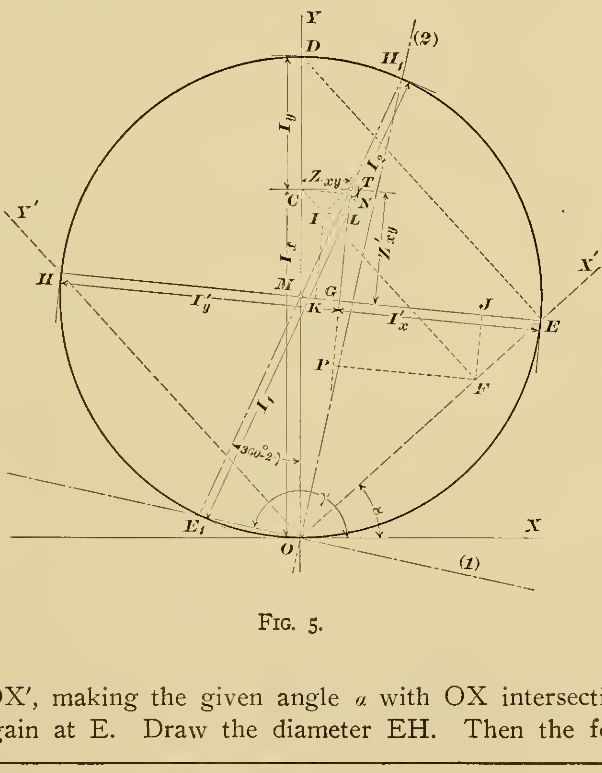


FIG. 5.

a line OX′, making the given angle $\alpha$ with OX intersecting the circle again at E. Draw the diameter EH. Then the foot, G,

*Proof. $\overline{OI'_x} = OE \cdot \cos\alpha + CE \cdot \sin\alpha$, and

$\overline{I'_xC} = OE \cdot \sin\alpha - CE \cdot \cos\alpha$ ; but

$OE = I_x \cos\alpha - Z_{xy}\sin\alpha$, and

$CE = I_y \sin\alpha - Z_{xy}\cos\alpha$ ; hence

$OI'_x = I_x \cos^2\alpha + I_y \sin^2\alpha - Z_{xy}\sin 2\alpha$, and

$I'_xC = \frac{1}{2}(I_x - I_y)\sin 2\alpha + Z_{xy}\cos 2\alpha$ ; hence by (3)

$OI'_x = I'_x$ and $I'_xC = Z'_{xy}$.

That $I'_x O' = I'_y$ follows obviously from (4).

†Civilingenieur, 1887, p. 43, and 1888, p. 123; Zeitschrift für Bauwesen, 1892, p. 550, and Hütte, 17 Aufl., p. 180.

of a perpendicular from T upon EH will be a point such that EG, GH and GT will represent $I'_x$, $I'_y$ and $Z'_{xy}$ respectively*,—$Z'_{xy}$ being positive or negative according as T is at right or left of EH, when E is made the *lowest point* of the circle.

Observe that the locus of G is a circle (not shown) on MT as a diameter.

5. *Principal Axes of Inertia and Extreme Values of I and Z.* From Fig. 4 it appears, since $I'_x$ is abscissa of C from O, that $I'_x$ can, with fixed origin, vary only between the limits $I_1$ ($= OI_1$) and $I_2$ ($=OI_2$), the former value for axis through O parallel to $AI_2$ (making C fall at $I_2$), the latter for axis parallel to $AI_1$ (making C fall at $I_1$). $AI_1$ and $AI_2$ are obviously perpendicular to each other, and the axes, O (1) and O (2), parallel respectively to them, are those which, for given origin, give extreme values for I. They are hence given the name principal axes of inertia, or, for short, principal axes.

Similarly, in Fig. 5, the extreme values of $I'_x$ are seen to be $TE_1$ and $TH_1$ ($E_1$ and $H_1$ being on a diameter through T), and $TE_1$ and $TH_1$ accordingly represent $I_1$ and $I_2$, and correspond respectively to the principal axes, O (1) and O (2), shown.

Both methods evidently afford an easy way of getting the principal axes when $I_x$, $I_y$ and $Z_{xy}$ are given.

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*Proof. Drop perpendiculars CF and DE on OE; TI on CF; FJ and IK on HE; IL, CN and FP on TG, extended if need be.

$$\text{Note that } OCF = ODE = CTI = EFJ = CFP = a$$
$$\text{and } OME = OCN = 2\,a$$
$$\text{and } ITN = FCN = OCN - OCF = a$$
$$\text{and } CTN = CTI + ITN = 2\,a$$

Then,

$$GE = JK + JE - GK$$
$$\text{But } JK = FI \cos CFP$$
$$= (CF - CI) \cos a = (I_x \cos a - Z_{xy} \sin a) \cos a$$
$$\text{and } JE = FE \sin EFJ = I_y \sin^2 a$$
$$\text{and } GK = IL = CT \cos CTI \sin ITL = Z_{xy} \cos a \sin a$$
$$\text{Hence, } GE = I_x \cos^2 a + I_y \sin^2 a - Z_{xy} \sin 2\,a$$
$$= I'_x \text{ by } (3).$$

$$\text{Moreover, } GH = HE - GE = OD - GE = I_x + I_y - I'_x$$
$$= I'_y \text{ by } (4)$$

$$\text{And } TG = NP + NT - PG$$
$$\text{But, } NP = CF \sin FCN = I_x \cos a \sin a$$
$$\text{and } NT = CT \cos CTN = Z_{xy} \cos 2\,a$$
$$\text{and } PG = FJ = FE \cos EFJ = I_y \sin a \cos a$$
$$\text{Hence, } TG = \tfrac{1}{2} (I_x - I_y) \sin 2\,a + Z_{xy} \cos 2\,a$$
$$= Z'_{xy} \text{ by } (3)$$

Note from Figs. 4 and 5, or from (3) by aid of differentiation, that for the principal axes $Z = 0$.* Hence, as we have seen that if either of the axes is an axis of symmetry, $Z = 0$, it follows that an axis of symmetry is a principal axis. There may be, of course, as for a circle, numerous sets of principal axes, but values of $I_x$ and $I_y$ will be the same for all of them.

Note also that Z may vary from $+ \frac{1}{2} (I_1 - I_2)$ to $- \frac{1}{2} (I_1 - I_2)$.

*6. Algebraic Means for Finding Principal Axes (O(1) and O(2)).* From Figs. 4 and 5, it appears that $\gamma$ being inclination of O(1) to OX, $\tan (360° - 2\gamma) = \frac{Z_{xy}}{\frac{1}{2}(I_x - I_y)}$, or

$$\tan 2\gamma = - \frac{2 Z_{xy}}{I_x - I_y} \quad \ldots\ldots\ldots\ldots \quad 5)$$

This would also appear from last of (3) by putting $Z'_{xy} = 0$ and using $\gamma$ for the resulting special value of $\alpha$.

Further, by substituting this value of $\gamma$ for $\alpha$ in first two equations of (3), or by inspection of Figs. 4 and 5, which are really (3) plotted, we find

$$\left.\begin{aligned} I_1 &= I_x - Z_{xy} \tan \gamma \\ I_2 &= I_y + Z_{xy} \tan \gamma \end{aligned}\right\} \quad \ldots\ldots\ldots \quad 6)$$

*7. Convenient Method for Calculating* $I_x$, $I_y$ *and* $Z_{xy}$ *in Special Cases.*† The $I_x$, $I_y$ and $Z_{xy}$ for center of gravity axes of any section divisible into two parts, for each of which are known the I's and Z for center of gravity axes parallel to the main set of axes, may conveniently be found as follows, without knowing the center of gravity of the whole figure.

This method is specially convenient for finding $Z_{xy}$ for angle irons,—a property not as yet given in the handbooks.‡

Let the section in Fig. 6 be one of this sort, and $G_1$ and $G_2$ be the centers of gravity of the two parts; $A_1$ and $A_2$ their areas; G and A the center of gravity and area of the whole figure. Then referring $A_1$ and $A_2$ to axes through their respective centers of gravity and parallel to GX and GY we have, by (2),

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*This is doubtless the reason why Z is not more prominent in the familiar works on applied mechanics. Most bars subjected to flexure are of symmetrical cross-section and can at once be referred to their principal axes, causing Z to escape attention.

†Müller-Breslau: op. cit., I, pp. 43, 44.

‡Such handbooks, however, as give the values of $\gamma$ as well as $I_x$ and $I_y$ enable one easily to find $Z_{xy}$ by the aid of (5).

$$I_x = I_{x_1} + A_1 \eta_1^2 + I_{x_2} + A_2 \eta_2^2$$

but $A_1 \eta_1 = A_2 \eta_2$ and $\eta_1 + \eta_2 = a$. It follows that

$\eta_1 = \dfrac{A_2\, a}{A_1 + A_2}$ and $\eta_2 = \dfrac{A_1\, a}{A_1 + A_2}$ whence $A_1 \eta_1^2 + A_2 \eta_2^2 = \dfrac{A_1 A_2 a^2}{A_1 + A_2}$

In like manner, it may be shown that $A_1 \xi_1^2 + A_2 \xi_2^2 = \dfrac{A_1 A_2 b^2}{A_1 + A_2}$ and that $A_1 \eta_1 \xi_1 + A_2 \eta_2 \xi_2 = \dfrac{A_1 A_2\, a\, b}{A_1 + A_2}$ and we can write

$$\left.\begin{aligned} I_x &= I_{x_1} + I_{x_2} + \frac{A_1 A_2 a^2}{A_1 + A_2} \\ I_y &= I_{y_1} + I_{y_2} + \frac{A_1 A_2 b^2}{A_1 + A_2} \\ Z_{xy} &= Z_{x_1 y_1} + Z_{x_2 y_2} + \frac{A_1 A_2\, a\, b}{A_1 + A_2} \end{aligned}\right\} \quad \ldots\ldots\ldots 7)$$

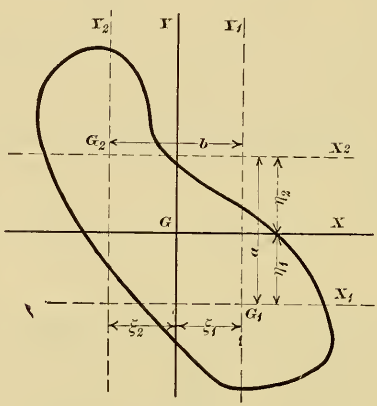


FIG. 6.

If $A_1$ and $A_2$ are referred to principal axes, $Z_{x_1 y_1}$ and $Z_{x_2 y_2} = 0$ and

$$Z_{xy} = \frac{A_1 A_2\, a\, b}{A_1 + A_2} \quad \ldots\ldots\ldots\ldots 8)$$

Formulas (7) and (8) may be most convenient for use even when center of gravity for whole figure is known, for they may involve fewer fractional quantities than other methods. If the center of gravity of the whole is known, however, (8) may be still further reduced, for from (2a) $Z_{xy} = A_1 \eta_1 \xi_1 + A_2 \eta_2 \xi_2$; and from $A_1 \xi_1 = A_2 \xi_2$ and $A_1 \eta_1 = A_2 \eta_2$, we can write (in such cases)

$$Z_{xy} = A_1 \xi_1\, a = A_2 \xi_2\, a = A_1 \eta_1\, b = A_2 \eta_2\, b \quad \ldots\ldots\ 8a)$$

The sign of $Z_{xy}$ will be correct if we see that it is given plus sign when the line $G_1G_2$ is in the first and third quadrants and minus sign otherwise.

The example of Section 24 will show how the results of this section are applied.

## PART II.

### DEVELOPMENT OF GENERAL FORMULAS.—GENERALITIES ABOUT THE NEUTRAL AXIS.

*8. General Formulas for Flexure in a Straight Bar.* Suppose the line of action of the resultant of all the forces on one side of a section of any straight bar pierce the section in question at K (Fig. 7), K being called for that reason the center of stress. Suppose nn to be the resulting neutral axis. Call N the component of the force at K normal to the section. Let the section be referred to axes GU and GV, with origin at the center of gravity G, and with the former parallel to nn, at distance $v_0$ from it. Then, since, as is generally accepted, within the elastic limit intensity of stress is proportional to the distance from the neutral axis, and calling the intensity of stress (or of the internal force) at any point whose ordinate is v, f, and at any point on GU, $f_0$, we can write $f : f_0 = (v + v_0) : v_0$ or

$$f = f_0 + \frac{f_0}{v_0} v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 9)$$

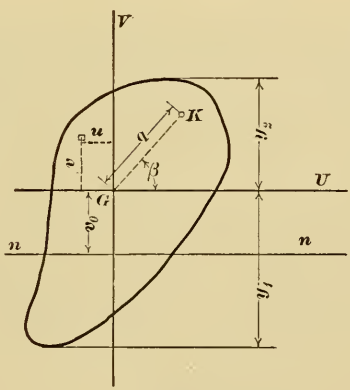

FIG. 7.

For equilibrium, the internal forces in the section must balance N. Hence, if q be the length of KG, and $\beta$ the inclination of KG (the trace of the plane of loads) to GU, and observing that N at K is equivalent to a force N acting at G plus a couple Nq in the plane KG, which in turn is equivalent to two couples, Nq sin $\beta$, and Nq cos $\beta$, in planes GV and GU respectively, it appears that the internal forces must together be equivalent to a system of forces consisting of a force of magnitude N acting at G, and two couples whose respective values are Nq sin $\beta$ and Nq cos $\beta$. Consequently

$\iint f\,dxdy = N$, $\iint v\,f\,dxdy = Nq \sin\beta$, and $\iint u\,f\,dxdy = Nq \cos\beta$

The undetermined constants in (9), $f_0$ and $\frac{f_0}{v_0}$, must be such as to give values of f consistent with these equations of equilibrium. Substituting in them the value of f from (9), and bearing in mind that $\iint dxdy = A$, $\iint v\,dxdy = 0$, $\iint u\,dxdy = 0$, $\iint v^2\,dxdy = I_u$, and $\iint u\,v\,dxdy = Z_{uv}$, it appears that

$$f_0 = \frac{N}{A} \text{ and } \frac{f_0}{v_0} = \frac{Nq \sin\beta}{I_u} = \frac{Nq \cos\beta}{Z_{uv}}$$

Inserting these values in (9), there result:

$$f = \frac{N}{A} + \frac{N\,q \sin\beta}{I_u} v \quad \dots\dots\dots\dots \quad 10)$$

or

$$f = \frac{N}{A} + \frac{Nq \cos\beta}{Z_{uv}} v \quad \dots\dots\dots\dots \quad 10')$$

From the equality of the two values of $\frac{f_0}{v_0}$, $\beta$ is determined

$$\operatorname{ctn} \beta = \frac{Z_{uv}}{I_u} \quad \dots\dots\dots\dots \quad 11)$$

Equation (10′) is not suitable for use in the familiar special case in which $\beta = 90°$, as then $\cos\beta$ and $Z_{uv}$ both vanish and (10′) becomes indeterminate. It may then be stated that *equations (10) and (11) are the fundamental and general equations for the study of unit stresses in flexure.** Flexure can here be understood to include the extremes, pure bending on the one hand and pure tension or compression on the other, as well as the intermediate cases of combined tension or compression and flexure. The equations hold for all inclinations of the plane of the bending forces.

There follow from (10), by substitution of special values for its various terms, the following equations for the interesting special cases:

For unit stress at extreme fiber, $v = y_1$ and $y_2$ ($y_1$ and $y_2$ will be of opposite signs),

$$f' = \frac{N}{A} + \frac{N\,q\,y_1}{I_u} \sin\beta\,; \quad f'' = \frac{N}{A} + \frac{N\,q\,y_2}{I_u} \sin\beta \quad \dots \quad 10a)$$

in pure flexure $N = 0$, and $q = \infty$, and $Nq = M$ and we have

$$f = \frac{Mv}{I_u} \sin\beta \quad \dots\dots\dots\dots \quad 10b)$$

*Though for practical application, it should be remarked that (11) requires the further transformation given it in Section 9, where it is restated in the form of two equations (13) and (14).

and $$f' = \frac{My_1}{I_u} \sin \beta;\ f'' = \frac{My_2}{I_u} \sin \beta \quad \text{10c)}$$

If in pure flexure the plane of loads includes a principal axis, $\beta = 90°$* and (10b) and (10c) become, dropping the suffix from $I_u$, the familiar expression

$$f = \frac{Mv}{I} \quad \text{10d)}$$

and $$f' = \frac{My_1}{I};\ f'' = \frac{My_2}{I} \quad \text{10e)}$$

For pure tension or compression q vanishes, and we have the familiar

$$f = \frac{N}{A} \quad \text{10f)}$$

To find the value of $v_0$, we need only determine in (10) or (10′) the value of v for zero values of f. Putting $f = 0$ in these equations, expressing $I_u$ and $Z_{uv}$ as $Ar_u^2$ and $Ar_u c_u$ (1) respectively, and noting that $q \sin \beta$ and $q \cos \beta$ are $v_k$ and $u_k$ respectively, there follows

$$v_0 = -\frac{r_u^2}{v_k} = -\frac{r_u\, c_u}{u_k} \quad \text{12)}$$

The negative sign shows that the neutral axis and center of stress are always on opposite sides of the center of gravity. The former of the two values for $v_0$ in (12) will be found preferable for use.

9. *Determination of the Direction of the Neutral Axis.* Equations (11) and (12) enable one at once to locate the K corresponding to any *given* neutral axis,† but the converse problem—the location of the neutral axis corresponding to a given K—cannot be dealt with until (11) has been radically transformed, for $Z_{uv}$ and $I_u$ cannot be known until the neutral axis is located. The difficulty can be met by introducing two new angles, the inclination of GK to GX, and of the neutral axis to GX. If the former be called $\lambda$, and the latter $\alpha$, $\beta$ will be the difference between them, or

$$\beta = \lambda - \alpha \quad \text{13)}$$

Here $\lambda$ is given, and $\alpha$ is to be found. Expressing $\beta$ as in (13), and $Z_{uv}$ and $I_u$, by (3), in terms of the given $I_x$, $I_y$ and $Z_{xy}$, and the desired $\alpha$, we can write (11) in the form

$$\operatorname{ctn}(\lambda - \alpha) = \frac{\frac{1}{2}(I_x - I_y) \sin 2\alpha + Z_{xy} \cos 2\alpha}{I_x \cos^2 \alpha + I_y \sin^2 \alpha - Z_{xy} \sin 2\alpha}$$

whence can be derived

---

*This appears from (11) which shows that if KG coincides with GV, and if GV is a principal axis, then (Section 5), $Z_{uv} = 0$ and $\beta = 90°$.

†See Sections 12 and 15 for numerical examples.

$$\tan \alpha = \frac{Z_{xy} - I_x \operatorname{ctn} \lambda}{I_y - Z_{xy} \operatorname{ctn} \lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 14)$$

whence, $\alpha$ being known, $\beta$ follows at once by (11), $I_u$ can be found by (3) v can be determined (as in Section 11 below) by proper transformation of co-ordinates and by (10) the desired f is found.

*10. General Equations.* The group of equations sufficing for all problems relating to the distribution of stress in cases of flexure in straight bars can be restated for reference as follows:

$$f = \frac{N}{A} + Nq \frac{\sin \beta}{I_u} v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 10)$$

$$\operatorname{ctn} \beta = \frac{Z_{uv}}{I_u} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 11)$$

$$v_0 = -\frac{r_u^2}{v_k} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 12)$$

$$\beta = \lambda - \alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 13)$$

$$\tan \alpha = \frac{Z_{xy} - I_x \operatorname{ctn} \lambda}{I_y - Z_{xy} \operatorname{ctn} \lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 14)$$

Of these, the last two are to be looked upon as mere derivatives (though indispensable ones) of (11). Equations (10), (13) and (14) suffice for most cases in practice*. Illustrations of their use in practical problems, together with some slight modifications possible in special cases, will be found in Sections 12 and 13 (Part III), and graphical means of attaining the same ends will be found developed and similarly illustrated in Sections 14-28 (Part IV).

*11. General Relations Between Neutral Axis and Point of Application (K) of External Force.* Let any section be referred to its principal axes (Sections 5 and 6). Then for any K upon either of these axes there will be a neutral axis parallel (by (14), $\lambda$ being 90° and $Z_{xy}$ zero) to the other axis. Thus, Fig. 8, the neutral axes for $K_1$ and $K_2$ are $n_1n_1$ and $n_2n_2$. Suppose $K_3$ anywhere upon line $K_1K_2$. The force at $K_3$ may be replaced by two components,—one at $K_1$, the other at $K_2$, for which by themselves the neutral axes would be $n_1n_1$ and $n_2n_2$. Under their combined influence, f will be zero at $K'$, the intersection of $n_1n_1$ and $n_2n_2$, therefore $K'$ must be a point on $n_3n_3$.

---

*It naturally suggests itself that these three equations might be combined, and, by aid of (3), and expressing v in terms of x and y, an expression for f obtained in terms of given quantities only. This promises little advantage in practice, however, especially as $\alpha$ must usually be separately evaluated in order to identify the point whose v is needed. Hence simplicity seems on the whole to be best conserved by the statement of the equations above printed.

Since $K_3$ is anywhere upon $K_1K_2$, it follows that $K'$ is a fixed point about which will revolve neutral axes for successive points on $K_1K_2$.

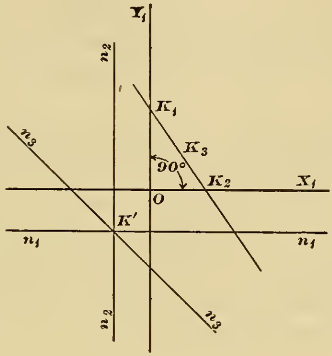


FIG. 8.

It follows, then, that (a) for a series of K's on any straight line, the corresponding series of neutral axes will rotate about a fixed point; and, conversely, (b) for a series of neutral axes rotating about a fixed point, the corresponding series of K's will lie on straight line.

The fixed point may be infinitely distant, of course, making the set of neutral axes parallel. This will be the case when the line of K's passes through the center of gravity of the section.

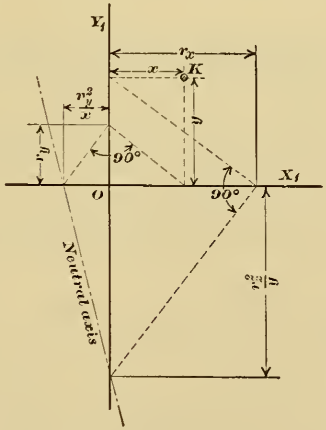


FIG. 9.

From (12) it appears, then, the figure being still referred to principal axes, $OX_1$, $OY_1$, that for any position (x, y) of K the neutral axis will have for intercepts on axes of X and Y, $\frac{r_y^2}{x}$ and

$\frac{r_x^2}{y}$ (Section 1) respectively. This fact may be used to aid in the construction of the neutral axis, and forms a convenient basis for a graphic method for it, as shown in Fig. 9. If K is at infinity, the neutral axis will be a line through the center of gravity parallel to the neutral axis for any K at finite distance from the origin on the given line GK.

Pure bending and pure axial stress arise from the extreme position of K,—at infinity and at the center of gravity, respectively. In the former case, the neutral axis passes through the center of gravity; in the latter, it is infinitely remote from the center of gravity. Other positions of K give rise to simultaneous axial stress (tension or compression) and bending, combined in proportions depending upon the remoteness of K.

## PART III.

### ALGEBRAIC APPLICATIONS.

*12. General Numerical Example.* Problem.—A 5″ × 3¼″ × ½″ Z-bar acts as a purlin on a roof whose slope is 30°, its top flange projecting toward the ridge. It supports vertical loads which cause a maximum bending moment of M inch-lbs. Required the extreme fiber stresses in the bar.

*Solution.* Taking origin at the center of gravity, with axes of X and Y respectively parallel and perpendicular to the flanges, $I_x$, $I_y$ and $Z_{xy}$ are calculated by (2a) as follows,* referring to Fig. 12:

$$I_x = \tfrac{1}{12}\,(3.25 \times 5^3 - 2.75 \times 4^3) = 19.19 \text{ in.}^4$$
$$I_y = \tfrac{1}{12}\,(.5 \times (3.25 + 2.75)^3 + 4.5 \times .5^3) = 9.05 \text{ in.}^4$$
$$Z_{xy} = 2\,(2.75 \times .5 \times 1.625 \times 2.25) = +\,10.05 \text{ in.}^4$$

$\alpha$ = inclination of neutral axis GU to GX.

$\lambda = 60° =$ inclination of plane of loads to GX.

Then by (14):

$$\tan\alpha = \frac{10.05 - 19.19 \times 0.577}{9.05 - 10.05 \times 0.577} = -\,0.314$$
$$\alpha = -\,17°\ 26'$$
$$\beta = \lambda - \alpha = 77°\ 26'$$
$$\sin\beta = 0.976$$

Extreme fibers referred to GX, GY are $(\pm\ 3.0,\ \pm\ 2.5)$, as appears from inspection after $\alpha$ is known.

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*$I_x$ and $I_y$ are also obtainable from the handbooks; and from such handbooks as give $\gamma$, the Cambria book for example, $Z_{xy}$ can be obtained by aid of (5).

$y_1 = -y_2 = (2.5 \cos \alpha - 3.0 \sin \alpha) = 3.285$ in., and by (3)
$I_u = 19.19 \cos^2 \alpha + 9.05 \sin^2 \alpha - 10.05 \sin 2\alpha = 24.02$ in.$^4$

Then by (10c):

$$f' = -f'' = M.\ \frac{3.285 \times 0.976}{24.02} = 0.133\ M$$

See Sections 15, 19, 25 and 28 for other solutions of this problem.

*13. Important Special Cases.** Case I.—*Trace of plane of bending (i.e., GK) coincident with Y-axis, making,* $\gamma = \alpha + \beta = 90°$.

Substitution of $\gamma = 90°$ in (14) yields

$$\tan \alpha = \frac{Z_{xy}}{I_y} = \operatorname{ctn} \beta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 15)$$

$\beta$ and $\alpha$ thus being known, (3) can be applied to get $I_u$, etc.

Value of $\dfrac{I_u}{\sin \beta}$ from (15) and (3) will prove to be

$$\frac{I_u}{\sin \beta} = I_x \sin \beta - Z_{xy} \cos \beta;$$

v of (10) may now be expressed in terms of x and y,

$$v = y \sin \beta - x \cos \beta;$$

substituting these values in (10), we have

$$f = \frac{N}{A} + Nq \left( \frac{y - x \operatorname{ctn} \beta}{I_x - Z_{xy} \operatorname{ctn} \beta} \right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 16)$$

This becomes, for pure bending when $N = 0$ and $q = \infty$, writing $Nq = M$,

$$f = M \left( \frac{y - x \operatorname{ctn} \beta}{I_x - Z_{xy} \operatorname{ctn} \beta} \right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 16a)$$

Equations (15) and (16) cover the cases of Z-bars and angles carrying loads normal to their flanges. Equation (15) determines $\beta$, and makes evident which must be the extreme fiber. The coördinates (x, y) of this point referred to GX and GY are found, and the sought for unit stresses determined by (16).

*Problem.* Suppose the purlin of Section 12 to be subject to wind load (normal to flanges) producing a bending moment of M′ inch-lbs. Required the extreme fiber stress.

*Solution.*

$I_x = 19.19$ in.$^4$; $I_y = 9.05$ in.$^4$; $Z_{xy} = +10.05$ in.$^4$, all as before.

By (11), $\beta = \operatorname{ctn}^{-1} \dfrac{10.05}{9.05} = \operatorname{ctn}^{-1} 1.110 = 42°\ 0'$

Extreme fibers will be seen by reference to figure to be at (— 0.25, 2.5) and (0.25, — 2.5). Then in (16a), $x = \mp 0.25$, $y = \pm 2.5$, and by (16a),

$$f = -f'' = M\ \frac{2.5 + 0.25 \times 1.110}{19.19 - 10.05 \times 1.110} = 0.345\ M' \text{ lbs. per sq. in.}$$

---

*Both of these special cases can, of course, easily be treated by general method of Section 9, but often less conveniently and less rapidly.

This is more than two and one-half times as great as would result if the neutral axis were normal to web of the bar.

See Sections 25 and 28 for other solutions of this problem.

Note that for combined effect of this load, and such a load as in Section 12, the values of f′ and f″ in the two cases cannot be added together, for the extreme fibers in the two cases are not identical. For correct result, values of f in each case can be found for its own extreme fiber and the extreme fiber for the other case, then f's for the same fiber can be combined and result obtained. The same might be done by finding the resultant of the two systems of loading and proceeding therewith anew.

Case II.—*Original axes GX and GY are also principal axes.**

In this case, $\lambda$ being inclination of trace of plane of bending GK to axis of X, unit stress at any point (x, y) may be expressed for general case of bending† (cf. Section 8)

$$f = \frac{N}{A} + \frac{Nq \sin \lambda\ y}{I_1} + \frac{Nq \cos \lambda\ x}{I_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 17)$$

or for pure flexure

$$f = \frac{M \sin \lambda\ y}{I_1} + \frac{M \cos \lambda\ x}{I_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 17a)$$

but if (x, y) is on nn (neutral axis), f will be zero and $\frac{y}{x} = \tan \alpha$. From these conditions it follows from substitution in the last equation that

$$\tan \alpha = -\frac{I_1}{I_2} \operatorname{ctn} \lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 18)$$

whence $\alpha$ can be found; but, Section 9, $\beta = \lambda - \alpha$.

The neutral axis being thus known, the co-ordinates of the extreme fiber (x, y) can be scaled off and inserted in (17). Sometimes these values of (x, y) are obvious by inspection and $\beta$ need not be found.

*Problem.* An 8-in.—18-lb. I-beam acts as purlin on a roof whose rise is one-fourth the span.

Required the fiber stress resulting from a moment of vertical loads of M in. lbs.

*Solution.* Here extreme fibers are obviously at top and bottom corners, *i.e.* at $(\pm 2.0 \pm 4.0)$; $\lambda = 63° 26'$, $I_1 = 56.9$ in.$^4$‡, $I_2 = 3.78$ in.$^4$‡

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*If principal axes and $I_1$ and $I_2$ are not given, they can always be found, if desired, either graphically or algebraically by Section 5 or Section 6.

†Note that value $\lambda$ making (17) a maximum determines most unfavorable plane of loads.

‡From handbooks.

By (17a), $f' = -f'' = M\left(\frac{0.894 \times 4.0}{56.9} + \frac{0.447 \times 2.0}{3.78}\right) = 0.300\ M$, that is $\frac{M}{3.33}$ against $\frac{M}{14.2}$ the value f′ or f″ for same loads in plane of the web of the beam.

See Sections 25 and 28 for other solutions of this problem.

# PART IV.

## Graphic Applications.

### I. METHOD BY THE CIRCLES OF INERTIA.

*14. Relation between the Circles of Inertia and Equation (10).* In equation (10) the quantities most commonly not given are $\beta$, $I_u$ and v. The last can be found by scaling, or transformation of co-ordinates as soon as $\beta$ is known, and the first step in the problem resolves itself into the determination of $\beta$ and $I_u$. This can be done, as is shown below, by a slight entension of either of the two circles of inertia of Section 4, and what is more $\frac{I_u}{\sin\beta}$ can be derived from either with no additional construction. The problem is then:

Given inclination of GK to OX (*i. e.* $\lambda$), $I_x$, $I_y$, and $Z_{xy}$: required $\beta$ and $\frac{I_u}{\sin\beta}$.

(a) *Müller-Breslau's Solution.**

From the data construct the circle of Fig. 4. Draw AD parallel to GK; produce OD to I; at I erect perpendicular to OO′ and produce it to a second intersection with the circle at C. Then† we shall have

$$CAF = DAA' = CIO = \beta$$

showing that AC is parallel to the neutral axis sought. Moreover, as shown in Section 4, $OI_u$ (abscissa of C) $= I_u$, $I_u C = Z_{uv}$

*Op. cit., I, pp. 52, 53.

†Proof (Fig. 10). $DAA' = CIO = \beta$

For $DAA' = 180° - DAC$ and

$DAC = \frac{1}{2}$ arc DQIBC;

but $CIO = \frac{1}{2}(360° - \text{arc DQIBC}) = 180 - DAC$

*i. e.* $DAA' = CIO$.

Moreover $CIO = \text{ctn}^{-1}\frac{I_u I}{O I_u} = \text{ctn}^{-1}\frac{I_u C}{O I_u} = \text{ctn}^{-1}\frac{Z_{uv}}{I_u}$

$\therefore$ by (11) $CIO = DAA' = \beta$. Q. E. D.

$= I_u I$ (AC being direction of GU) and $OI = \frac{I_u}{\sin \beta}$. The resulting work is shown in Fig. 10, $I_x$ being taken greater than $I_y$ as usual, and $Z_{xy}$ being supposed to be given as positive.

A line drawn through center of gravity of the section parallel to AC will be the GU of Section 8, and $y_1$ and $y_2$ can then be scaled and extreme fiber stresses can be found by (10a). The neutral axis will be parallel to GU at a distance $\frac{r_u^2}{q \sin \beta}$ (12) on opposite side of G from K.

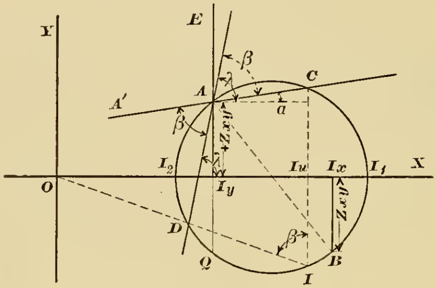


FIG. 10.

It tends to compactness to draw the section with its center of gravity coinciding with A, then AC will be at once in place for GU, and if, as usually is the case, $q = \infty$,—*i.e.*, if there is pure flexure,—it will also be the neutral axis itself.

*Remark.* If, in Fig. 10, C or D should be near A, poor intersections with the circle might cause inaccuracy. This difficulty can be avoided by omitting the circle and getting the same construction as follows:

Drop a perpendicular from B on the line through A parallel to GK and get D; make CAE = ODA* (measuring clockwise from AE and get the line AC); drop a perpendicular from B on AC and get C; drop from C a perpendicular on OX and produce it till it meets OD; this perpendicular will cut OX in $I_u$ and OD in I.

(b) *Mohr-Land Solution.*† From the data construct, Fig. 11, the circle of Fig. 5, locating T. Draw AO parallel to GK; produce AT to second intersection with circle at E. Draw EM to

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*CAE = ODA for their supplements CAQ and ADI are measured by the equal arcs QIBC and IBCA.

†R. Land; Einfache Darstellung der Trägheits- u. Centrifugalmomente von Flächen, Zeitschrift für Bauwesen, 1892, p. 554, a condensation of which is to be found in Hütte Taschenbuch, 17te Aufl., p. 345.

second intersection with circle at H, and draw the straight line OEU. Then* we shall have

$$UOA = ETG = \beta$$

showing that OU is parallel to the neutral axis sought. Moreover, as shown in Section 4, $EG = I_u$, $GT = Z_{uv}$, and obviously $ET = \dfrac{I_u}{\sin\beta}$

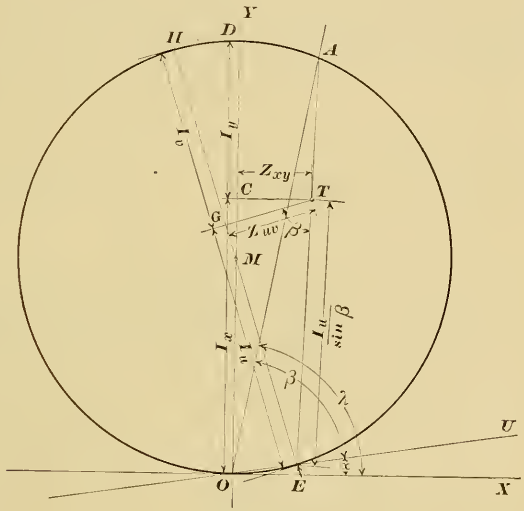


FIG. 11.

Then, precisely as in the preceding method, a line drawn through the center of gravity of the section parallel to OU will be the GU of Section 8; $y_1$ and $y_2$ can then be scaled and extreme fibre stresses can be found by (10a).

If the neutral axis be required, it can be located by drawing a parallel to it at a distance $\dfrac{r_u^2}{q\sin\beta}$ (12) on the opposite side of G from K.

Observe that Fig. 11 is drawn with the same data as Fig. 10.

*Proof (Fig. 11). $UOA = ETG = \beta$

Draw OH, then $UOH = 90° = \frac{1}{2}$ arc EADH

and $AOH = 90° - UOA$.

But $AOH = AEH = \frac{1}{2}$ arc HDA

and $AEH = 90° - ETG$;

therefore $UOA = ETG$, their complements being equal.

But $ETG = \text{ctn}^{-1}\dfrac{Z_{uv}}{I_u}$

∴ by (11) $UOA = ETG = \beta$. Q. E. D.

It will be found convenient to make O in this method coincident with the center of gravity of the section just as was the case with A in the preceding method.

*15. Example.* A 5″ x $3\frac{1}{4}$″ x $\frac{1}{2}$″ Z-bar acts as a purlin on a roof whose slope is 30°, its top flange projecting toward the ridge. It supports vertical loads which cause a maximum bending moment of M inch-lbs. Required the extreme fiber stresses in the bar.

*Solution.* It will be observed that this is the same problem as that of Section 12, and that here, as there, we have

$$I_x = 19.19 \text{ in.}^4,\ I_y = 9.05 \text{ in.}^4,\ Z_{xy} = +\ 10.05 \text{ in.}^4$$

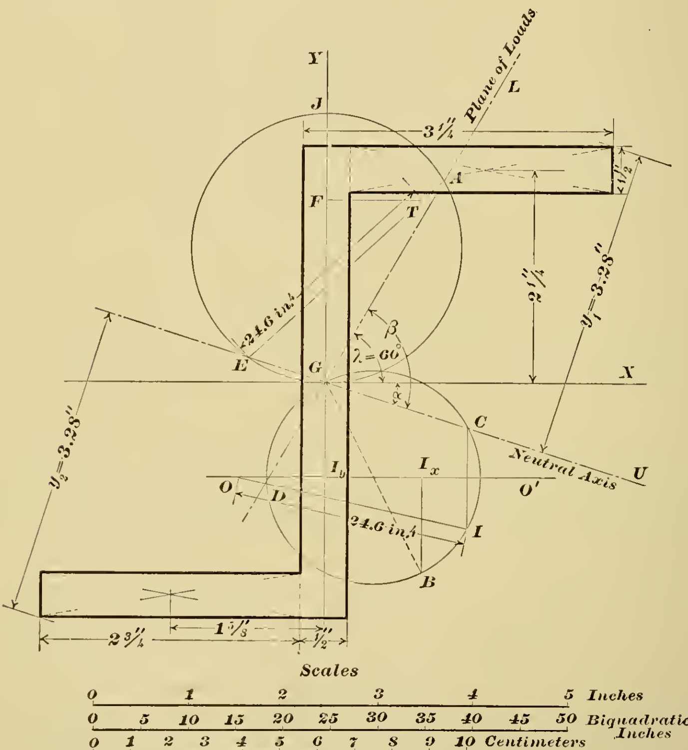


FIG. 12.

From these data must be found $\frac{I_u}{\sin\beta}$, $y_1$ and $y_2$ for substitution in (10b). This can be done graphically by either of the circles of inertia of the preceding section, and both will now be worked out in Fig. 12.

Draw (Fig. 12) the section of the bar, the gravity axes, GX and GY, and the trace, GL, of the plane of the loads, making an angle, $\gamma$, of 60° with GX. Then can be executed the

*(a) Solution by the Müller-Breslau Circle of Inertia (Section 14a).* Lay off $GI_y$ (= 10.05 in.[4]) downward along GY, and $I_yO$ (= 9.05 in.[4]), parallel to GX, toward the left.* Extend $OI_y$ to O′. Along OO′ lay off $OI_x$ (= 19.19 in.[4]), and then $I_xB$ (= $GI_y$) vertically downward. On GB as a diameter construct a circle. Through D the second intersection of GL with the circle, draw OD to second intersection at I. Draw from I a normal to OO′ to second intersection at C.

Then $OI = \frac{I_u}{\sin\beta} = 24.6$ in.[4], GC is the neutral axis for this case of loading and $y_1 = -y_2$ are scaled off, and found to be 3.28 in. By (10b),

$$f' = -f'' = \frac{3.28}{24.6}M = 0.133\ M. \quad \text{Ans.}$$

*(b) Solution by the Mohr-Land Circle of Inertia (Section 14b).* Lay off, Fig. 12 GF (= 19.19 in.[4]), and FJ (= 9.05 in.[4]) upward along GY. From F parallel to GX toward the right lay off FT (= 10.05 in.[4]). On GJ as a diameter construct a circle. A being the second intersection of GL with this circle, draw AT to a second intersection at E.

Then $ET = \frac{I_u}{\sin\beta} = 24.6$ in.[4], GE is the neutral axis for this case of loading and $y_1 = -y_2$ are scaled off, and found to be 3.28 in. By (10b),

$$f' = -f'' = \frac{3.28}{24.6}M = 0.133\ M. \quad \text{Ans.}$$

See Sections 12, 19, 25 and 28 for other solutions of this problem.

Note also that result is very sensitive to change in $\gamma$. This is still more strikingly seen upon examination of the kernel method in Section 25.

The problems of Section 13 might well be worked out by the aid of a circle of inertia by the reader desiring further practice.

## II. METHOD BY THE ELLIPSE OF INERTIA.

*16. Ellipse of Inertia.* Though the preceding twelve sections furnish a means of dealing in general with problems involving moments and products of inertia and neutral axes, the discussion would not be complete without reference to the ellipse

*This causes $I_y$ to be at the right of O, and G to be above OO′ as it should be (Section 4) for positive $Z_{xy}$.

of inertia and its remarkable properties. Moreover, the ellipse of inertia offers some advantage in clearness of representation to the mind the facts of the case. It affords a ready means of rough mental check on location of neutral axis by other means, and, for that matter, an exact check if desired. It will be discussed briefly in this and the following three sections.

If a section be referred to a series of X-axes rotating about a fixed point O, and for each position of the axis parallels to it be drawn at distances $\pm r_\alpha$ (where $r_\alpha = \sqrt{I_\alpha / A}$ and $I_\alpha$ is I for any axis at angle $\alpha$ with original axis) it can be shown that these parallels will envelop an ellipse with center at O and with $r_1$ and $r_2$ as semi-major and semi-minor axes respectively. If, then, the ellipse of inertia is given, the $I_x$ for any axis OX can be determined by drawing a tangent to ellipse parallel to OX; the distance between these parallels will be $r_x$, and $I_x = A\ r_x^2$.

Moreover, if tangents to the ellipse be drawn parallel to OX and OY, the co-ordinates of the four points of tangency will be found to be, in the notation of Section 1 $(\pm r_y, \pm c_y)$ for the tangents parallel to OX and $(\pm c_x, \pm r_x)$ for those parallel to OY. For principal axes, $c_x$, $c_y$ and $Z_{xy}$ will all vanish, as already shown in Section 5. Sign of $Z_{xy}$ shows which way ellipse will incline,— for $+ Z_{xy}$ major axis will traverse the first and third quadrants; for $- Z_{xy}$, the second and fourth.

It appears, then, that with the ellipse of inertia given we are in position to get directly the values of $I'_x$, $I'_y$ and $Z'_{xy}$ for any set of rectangular axes through O, and, by the aid of (2a), about any axes whatever. The ellipse of inertia forms a second graphical solution for (3). See Section 19 for example.

17. *Central Ellipse and its Relation to Neutral Axes.* If the ellipse of inertia has the center of gravity of the section for its center, it is then called the central ellipse of the section. Its principal axes are evidently the principal axes of inertia (Section 5) of the section.

The major axis will coincide with that axis of symmetry which traverses the longer way of the section. If there be no axis of symmetry, the major axis will, in a general way, follow the longer trend of the section.

The central ellipse is specially important, for, besides having the same properties as any other ellipse of inertia, it affords a very good means of determining the position and slope of the neutral axis for any K. If we connect the points of tangency with the ellipse of two tangents through K, the neutral axis will be parallel

to this chord, and will be just as far beyond G as G is beyond the chord. The neutral axis is then parallel to the conjugate to the diameter coincident with trace of plane of loads. We must observe further that the relation between K and the chord is that of pole and polar and that the relation between K and neutral axis is consequently that of pole and anti-polar, so called, with respect to the central ellipse.

*18. Method of Finding Points of Tangency.* (See Fig. 13.) If $F_1$ and $F_2$ be the two foci, with K as center and $KF_1$ as radius, describe a circle; describe another with $F_2$ as center and major

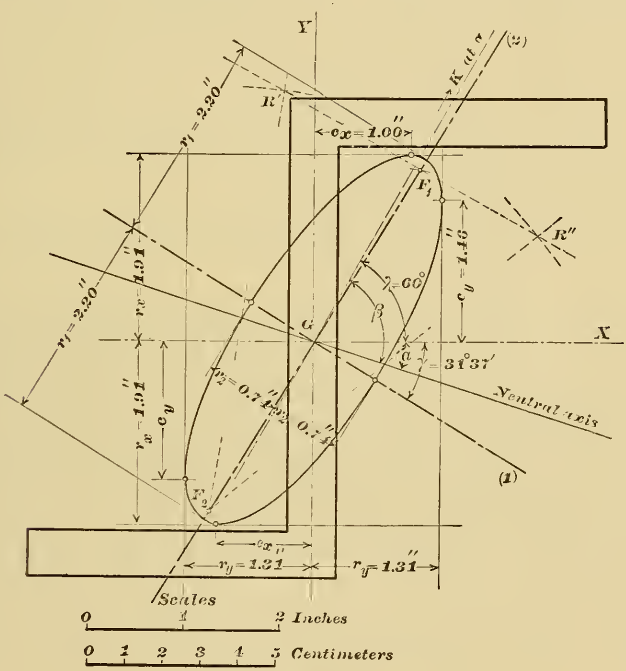


FIG. 13.

diameter of ellipse as radius. Call the intersections of these two circles R′ and R″. Where $F_2R'$ and $F_2R''$ cut the ellipse are the points of tangency of tangents through K. This holds, of course, where K is at infinity, but fails if K is within the ellipse. In the latter case, the neutral axis can still be found, because a second K outside the ellipse on the line GK will determine its slope, and (20), its position,—$r'_u$ being in this case the semi-diameter of the ellipse coinciding with GK.

*19. Example.* Fig. 13 shows an ellipse of inertia, with dimensions, to illustrate Section 17. The case chosen is the central

ellipse of the Z-bar of Section 12, and the neutral axis for the circumstances there described is here again worked out. There remain to be found from the drawing $r_u$ (whence can be determined $I_u = A\ r_u^2$), $\beta$, $y_1$ and $y_2$ and then f′ and f″ can be found by (10c), as in Section 12.

An ellipse of inertia is easily constructed from its semi-major and semi-minor axes after finding their length and slope by Sections 5 or 6. The work for Fig. 13 is the following:

$I_x = 19.19$ in.$^4$; $I_y = 9.05$ in.$^4$; $Z_{xy} = +\ 10.05$ in.$^4$ as in Section 12.

$$A = 2 \times 2.75 \times 0.5 + 5 \times 0.5 = 5.25 \text{ in.}^2$$

$$\text{By (5)} \tan 2\gamma = -\frac{2\,Z_{xy}}{I_x - I_y} = -\frac{2 \times 10.05}{19.19 - 9.05} = -1.982$$

$$2\gamma = -63^\circ\ 14'$$

$$\gamma = -31^\circ\ 37'$$

$$\text{By (6) } I_1 = I_x - Z_{xy} \tan\gamma = 19.19 + 10.05 \times 0.616 = 25.3808 \text{ in.}^4$$

$$r_1 = \sqrt{\frac{I_1}{A}} = \sqrt{\frac{25.3808}{5.25}} = 2.20 \text{ in.}$$

$$I_2 = I_y + Z_{xy} \tan\gamma = 9.05 - 10.05 \times 0.616 = 2.86 \text{ in.}^4$$

$$r_2 = \sqrt{\frac{I_2}{A}} = \sqrt{\frac{2.86}{5.25}} = 0.74 \text{ in.}$$

Constructing the central ellipse, and locating the neutral axis (as per Sections 17 and 18), we reach the result shown in Fig. 13.

The perpendicular distance, $r_u$, between a diameter parallel to the neutral axis (the diameter and the axis are coincident in cases of pure flexure) and a parallel tangent (not shown) to the ellipse, can now be scaled off as 2.14 in. (making $I_u = A\ r_u^2 = 5.25 \times 2.14^2 = 24.04$ in.$^4$), $\beta$ and $y_1$ and $y_2$ can be taken from the drawing for insertion in (10a) and same values for f′ and f″ reached as before.

See Sections 12, 15, 25 and 28 for other solutions of this problem.

### III. KERNEL METHOD.*

20. *Kernel of a Section.* If the neutral axis crosses the section, both tension and compression will exist in the section,—one on one side of the neutral axis, the other on the other. If the neutral axis touches, but does not cut the section, the stress in the section will be of the same sign throughout its area. If, for a series of such tangential axes enveloping the whole section, the corresponding K's be found, they will inclose a polygon having

*Relation between the kernel and unit stresses was pointed out first by Prof. W. Ritter, of Zurich. It is stated in his Anwendungen der Graphischen Statik I, p. 56.

a remarkable bearing on our subject. This polygon may be called the kernel of the section.

The kernel evidently defines an area outside of which a force cannot be applied without calling into play both tensile and compressive stresses. The familiar middle-third rule of masonry construction is an application of this principle,—the kernel of a rectangle being a lozenge whose center is at the center of the rectangle, whose axes of symmetry are coincident with those of the rectangle and whose diagonals are each one-third the length of the side of the rectangle to which they are parallel.

A far more important feature of the kernel is the remarkable aid it can be made to afford in the solution of the complicated problem which forms the subject of this paper. Kernels* for the standard rolled sections *once constructed and made accessible for reference,* like the tables of other properties of rolled shapes, would make it *but a moment's work for any draftsman* to compute the extreme fiber stresses for these sections for any case of bending in a straight bar, or of combined bending and tension or compression. The demonstration and formulation of the kernel method is taken up in the next several sections.

*21. Oblique Co-ordinates.* The kernel method is based upon the form taken by equations (8), (10) and (8a) when referred to certain oblique axes. Suppose axis of V in Fig. 7 be made to pass through K wherever K may be, we obtain in general oblique axes inclined to each other by $\beta$. For such axes, $\beta$ disappears from equations of Section 8 if $v'$, $I'_u$, $r'_u$, $y'_1$, $y'_2$ be substituted for $v$, $I_u$, $r_u$, $y_1$, $y_2$, respectively. Here the new quantities are simply those resulting from use of oblique co-ordinates in place of rectangular ones, and are found by dividing the old quantities by $\sin\beta$, or by $\sin^2\beta$,—by the latter in case of $I'_u$, by the former in case of the rest. Making these substitutions in (10), (12) and (10a), there result the equations

$$f = \frac{N}{A} + \frac{Nq\ v'}{I'_u} \quad . \ . \ . \ . \ . \ . \ . \ . \quad 19)$$

$$v'_0 = -\frac{r'^2_u}{q} \quad . \ . \ . \ . \ . \ . \ . \ . \quad 20)$$

$$f' = \frac{N}{A} + \frac{Nq\ y'_1}{I'_u}\ ; \qquad f'' = \frac{N}{A} + \frac{Nq\ y'_2}{I'_u} \quad . \ . \ . \ . \quad 21)$$

*22. Extreme Unit Stresses in Terms of Kernel Radii.* Let (Fig. 14) any section and its kernel (the shaded area) be given,

*Either to true scale, or better to a scale exaggerated in accordance with Sections 26-28. In the latter case, the resulting figures may well be called resistance polygons.

and let axes be taken as in Section 21. Then neutral axes for all points K on GV will be parallel to GU (Section 11).

If q′ be the ordinate of any K, we have by (20) $v'_0 = -\frac{r'^2}{q'}$ whence dropping the sign (Section 8) $q' = \frac{r'^2}{v'_0} = \frac{I'_u}{A\,v'_0}$.

Call the points of kernel perimeter lying on GK, $K_1$ and $K_2$, the former being the point on opposite side of G from K. Then, by construction, $K_1$ and $K_2$ are points for which the corresponding neutral axes would be tangents to the figure and be parallel (Section 11) to the neutral axis for K. The constant ordinates of these tangents $y'_1$ and $y'_2$ will therefore be the ordinates of the

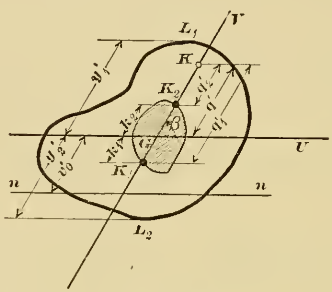

FIG. 14.

extreme fibers for the case in hand. These ordinates have, however, a relation with $k_1$ and $k_2$, expressed by (20) (the $k_1$ and $k_2$ taking the place of q, and $y'_1$ and $y'_2$ of $v'_0$, and $Ar'^2_u$ being replaced by $I'_u$.)

$$k_1 = \frac{I'_u}{A\,y'_1}\,; \qquad k_2 = \frac{I'_u}{A\,y'_2}$$

whence it appears that $\frac{I'_u}{y'_1} = A\,k_1$ and $\frac{I'_u}{y'_2} = A\,k_2$.

Substituting these values in (21) and expressing the necessary diversity of sign between $k_1$ and $k_2$, we get

$$f' = \frac{N}{A} + \frac{N\,q'}{A\,k_1}\,; \quad f'' = \frac{N}{A} - \frac{N\,q'}{A\,k_2} \quad \ldots\ldots\ldots \quad 22)$$

This becomes, on substituting $q'_1$ and $q'_2$ for $q' + k_1$ and $q' - k_2$, respectively

$$f' = \frac{N\,q'_1}{A\,k_1}\,; \; f'' = -\frac{N\,q'_2}{A\,k_2} \quad \ldots\ldots \quad 23)$$

and for pure flexure

$$f' = \frac{M}{A\,k_1}\,; \; f'' = -\frac{M}{A\,k_2} \quad \ldots\ldots \quad 23a)$$

the equations sought.

Observe that the most favorable and least favorable planes of loading will have for their traces lines running from the center of gravity of the figure to most remote and least remote points of kernel respectively.

*23. Construction of Kernels.* The kernel for any figure can be constructed by finding the principal axes (Sections 5 and 6), and then locating the desired K's by the converse of Fig. 9. Or, for that matter, each vertex of the figure through which a tangent can be passed may be treated as a K, for which the corresponding neutral axis will be a side of the kernel, involving, of course, the direct method of Fig. 9. It will often be found convenient to combine these two methods.

A second method makes use of the central ellipse. It is really only another phase of the method just given and the one about to be described, and needs no further mention.

A third method can be developed which is somewhat more simple than either of the foregoing, in that it does not require the aid of the principal axes, and is, hence, specially useful in the case of some steel shapes, as angles and Z's, whose principal axes are not so naturally chosen for reference as axes parallel to the two legs or to the web and flanges, as the case may be.

Most of the tangents to these shapes are parallel to these axes, and we have the exact conditions of Section 8 with the location of the K for a given nn as our problem, which will now be solved.

Using the notation of Section 8, and calling $(u_k, v_k)$ the desired co-ordinates of K, we have at once from (12)

$$v_k = -\frac{r_u^2}{v_0} = -\frac{A\,r_u^2}{A\,v_0} = -\frac{I_u}{A\,v_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 24)$$

$$u_k = -\frac{r_u\,c_u}{v_0} = -\frac{A\,r_u\,c_u}{A\,v_0} = -\frac{Z_{uv}}{A\,v_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad 25)$$

For tangents parallel to GV, $I_v$ and $u_0$ would of course replace $I_u$ and $v_0$ in these equations, and $u_k$ would be given by (24) and $v_k$ by (25).

If the complete kernel is sought (which is often unnecessary, one side sufficing in many practical cases), one or more additional tangents inclined to the given axes may remain to be treated. This can be done (a) by finding the I and Z for axes parallel and perpendicular to the tangent in question by use of (3) or method of Fig. 4, calculating or scaling v, and applying (24) and (25) as before, or (b) by use of (11a) and (10) if necessary, locate, as sides of the kernel, neutral axes for K's corresponding to extreme points of tangency of the inclined tangent.

See Section 24 for numerical examples.

*24. Examples of Kernel Construction.* 1. Required the kernel of an angle iron. Taking for example an angle $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ or (using Müller-Breslau's device of expressing dimensions in terms of the thickness of the metal) a 10t x 8t x t angle, where t

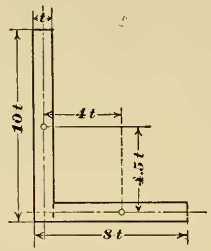


FIG. 15.

will in this case equal 0.25″. Taking all axes, Fig. 15, parallel to the flanges (or legs), we have by (7) and (8) ($I_x$ and $I_y$ can be taken from handbooks also),

$$I_x = \tfrac{1}{12}\,(1 \times 10^3 + 7 \times 1^3)\,t^4 + \frac{7 \times 10}{7 + 10} \times 4.5^2\,t^4 = 167.299\,t^4$$

$$I_y = \tfrac{1}{12}\,(1^3 \times 10 + 1^3 \times 7)\,t^4 + \frac{7 \times 10}{7 + 10} \times 4^2\,t^4 = 95.299\,t^4$$

$$Z_{xy} = -\frac{7 \times 10}{7 + 10} \times 4 \times 4.5\,t^4 = -74.118\,t^4.$$

By method of Section 5 we find, Fig. 16a, $I_1$ and $I_2$ and the principal axes. From the figure are scaled $I_1 = 214.0\,t^4$ and $I_2 = 48.6\,t^4$, whence, A being $17\,t^2$,

$$r_1 = \sqrt{\frac{214\,t^4}{17\,t^2}} = 3.55\,t = 0.89 \text{ in.},$$

$$r_2 = \sqrt{\frac{48.6\,t^4}{17\,t^2}}. = 1.69\,t = 0.42 \text{ in.}$$

The kernel is then found to be the shaded area of Fig. 16b by first method explained in Section 23.*

Construction lines are omitted for clearness except for point A and corresponding line a, and for line AB and the corresponding point (ab).

Vertices and sides of the kernel are marked throughout with the same letters as the corresponding sides and vertices of the

*$I_x$, $I_y$ and $Z_{xy}$ were calculated with the usual approximation of neglecting fillets, and rounding of corners. In constructing the kernel, however, a slight inconsistency was introduced in constructing c for a CD drawn tangent to the angle as actually rolled. The change in c is very slight.

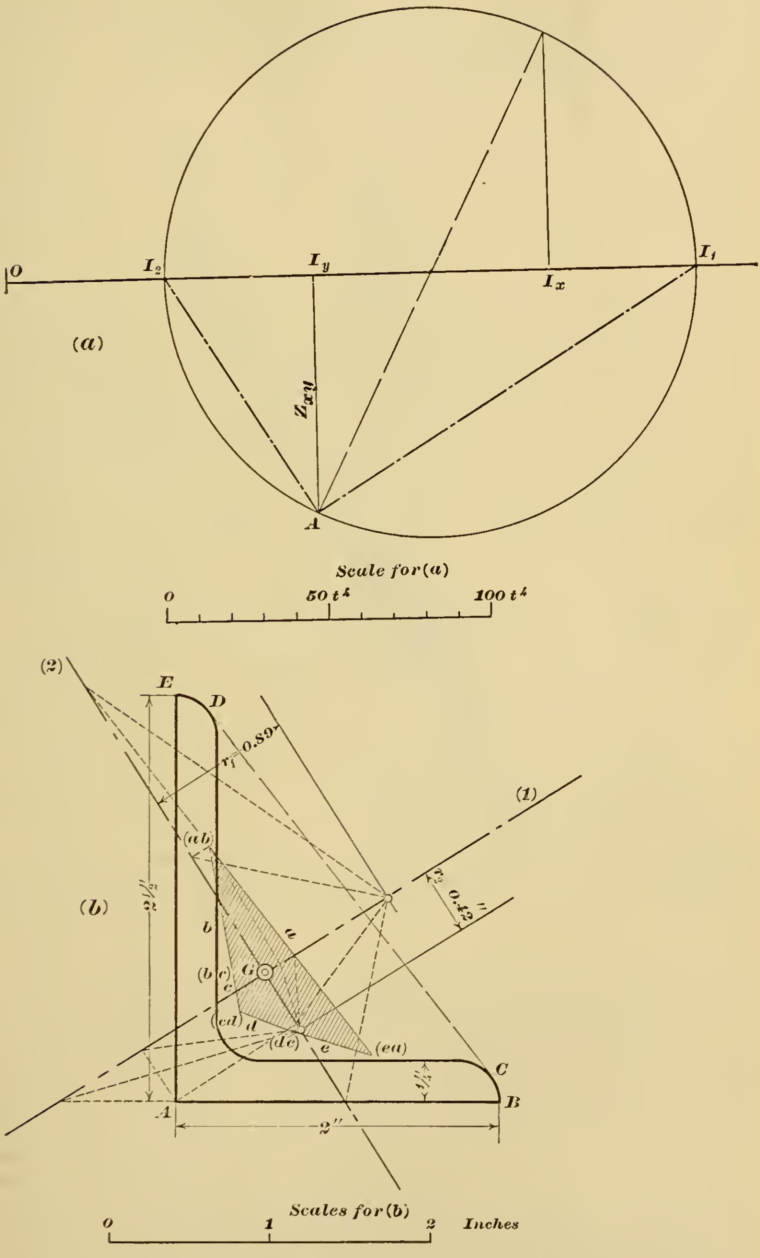
O
$I_2$
$I_y$
$I_x$
$I_1$
(a)
$Z_{xy}$
A
Scale for (a)
0
50 t⁴
100 t⁴
(2)
E
D
0.89″
$r_1$
(1)
(ab)
(b)
$2\frac{1}{2}''$
b
a
(bc)
G
c
(cd)
d
(de)
e
(ea)
0.42″
$r_2$
C
B
A
$\frac{1}{4}''$
2″
Scales for (b)
0
1
2
Inches
0
1
2
3
4
5
Centimeters

FIG. 16.

angle. Of course, the kernel can be constructed either by finding its vertices alone or its sides alone, or by combination of the two methods, as may be most convenient.

2. Required the kernel of a 5″ x $3\frac{1}{4}$″ x $\frac{1}{2}$″ Z-bar.

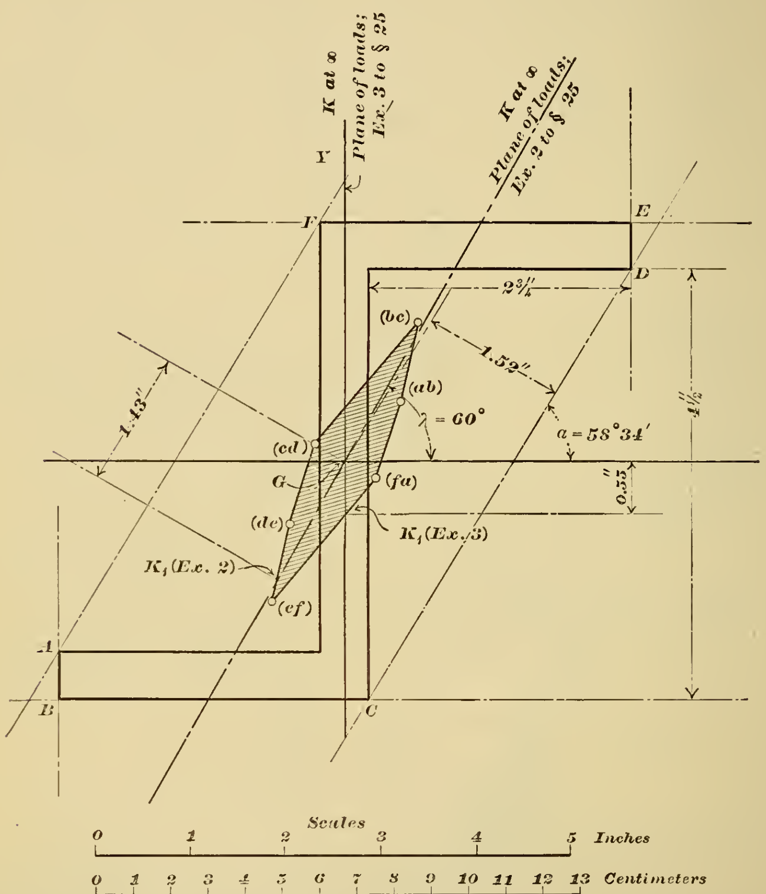


Fig. 17.

*Solution.* Given, from Section 12: $I_x = 19.19$ in.$^4$; $I_y = 9.05$ in.$^4$; $Z_{xy} = + 10.05$ in.$^4$ Found, by calculation, $A = 5.25$ in.$^2$

The section (Fig. 17) has six tangents, of which only three, AB, BC and CD, call for computation. Symmetry will provide for the other three.

By (24) and (25):

(x, y) for (ab), $v_0$ being $-3.0$ in.,

$$x = -\frac{9.05}{-3.0 \times 5.25} = 0.57 \text{ in.}$$

$$y = -\frac{10.05}{-3.0 \times 5.25} = 0.64 \text{ in.}$$

(x, y) for (bc), $v_0$ being $-2.50$ in.,

$$x = -\frac{10.05}{-2.5 \times 5.25} = 0.77 \text{ in.}$$

$$y = -\frac{19.19}{-2.5 \times 5.25} = 1.46 \text{ in.}$$

These points can now be plotted, and also (de) and (ef), which are respectively symmetrical with (ab) and (bc) with respect to the center of gravity. Then if the slope of (bc) (cd) and of (cd) (de) can be determined these two lines can be drawn, and (ef) (fa) and (fa) (ab) being parallel to them the kernel can be completed. This can be done upon the principle that (bc) (cd) and (cd) (de) are neutral axes for K's assumed respectively at C and D, for which the slopes can be found by (14) or by one of the circles, or by the ellipse of inertia.

Using (14), in which can be inserted ctn $\lambda = \frac{x}{y}$ for point (x, y), we have for C, ctn $\lambda = -\frac{0.25}{2.50} = -0.10$, and, for D, ctn $\lambda = \frac{3.0}{2.0} = 1.50$.

For (bc)(cd), $\tan \alpha = \frac{10.05 + 19.19 \times 0.10}{9.05 + 10.05 \times 0.10} = \frac{11.969}{10.055} = 1.190$

For (cd)(de), $\tan \alpha = \frac{10.05 - 19.19 \times 1.50}{9.05 - 10.05 \times 1.50} = \frac{18.735}{6.025} = 3.143$

The four remaining sides are now determined, by the slope of each and a point in each being known, and the kernel is established.

Observe that fillets are neglected in accordance with the usual practice in this country.

See also Section 25 for construction of kernel of an I beam.

25. *Examples of Use of Kernel for Determining Unit Stresses.*

1. Required extreme unit stresses f′ and f″ in a $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ angle iron, subject as a strut to a force of N pounds parallel to its axis and applied (taking A of Fig. 16 as origin and AB and AE as axes of X and Y respectively) at (0.54, $-0.125$), a point K, in a line from G perpendicular to the short leg.

*Solution.* Taking the kernel from Fig. 16, draw, Fig. 18, a straight line from K to G and on through the kernel; its first intersection with the kernel perimeter will be $K_2$ and its second $K_1$. Scaling the $q'_1$, $k_1$, $q'_2$ and $k_2$ of (23), they are found to be 1.24 in., 0.32 in., 0.62 in. and 0.29 in. respectively. Hence, A being 1.06 in.$^2$, f′ and f″ are found by (23).

$$f' = \frac{N}{1.06} \times \frac{1.24}{0.32} = 3.6 \text{ N lbs. per sq. in. compression at } L_1$$

$$f'' = -\frac{N}{1.06} \times \frac{0.62}{0.29} = 2.0 \text{ N lbs. per sq. in. tension at } L_2$$

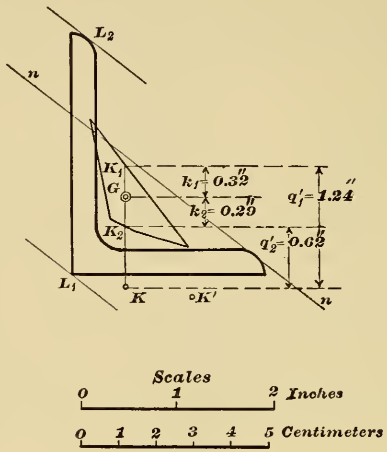


FIG. 18.

Similarly for any other K. This method simplifies the study of the effect of securing an angle strut or tie by rivets through one leg only.

It will be observed at once that loads may be applied with greater eccentricity than in this case, as at K′, and still produce smaller stresses in the member.

As a matter of interest, neutral axis, nn, and extreme fibers, $L_1$ and $L_2$, for K are shown, but observe that they were not needed for the solution of this problem.

2. A 5″ x $3\frac{1}{4}$″ x $\frac{1}{2}$″ Z-bar acts as a purlin on a roof whose slope is 30°, its top flange projecting toward the ridge. It supports vertical loads which cause a maximum bending moment of M inch-lbs. Required the extreme fiber stress in the bar.

*Solution.* In Fig. 17, drawing GK making $\lambda = 90° - 30° = 60°$, $K_1$ is located; $GK_1$ is $k_1$ as well as $-k_2$ of (23). Its value is scaled off as 1.43 in.

Then by (23a), A being 5.25 in.²,

$$f' = -f'' = \frac{M}{5.25 \times 1.43} = \frac{M}{7.51} = 0.133 \text{ M. Ans.}$$

as found in the other solutions of this problem in Sections 12, 15, 19 and 28.

3. Suppose the purlin of the last example to be subject to wind load normal to flanges producing a bending moment of M′ inch-lbs. Required the extreme fiber stress.

*Solution.* From Fig. 17, $GK_1$ is scaled off as 0.55 in. Substituting in (23a)

$$f' = -f'' = \frac{M'}{5.25 \times 0.55} = \frac{M'}{2.89} = 0.346\,M'. \quad \text{Ans.}$$

which agrees acceptably with result for same problem in Sections 13 and 28.

4. An 8 in. — 18-lb. I beam acts as a purlin on a roof whose rise is one-fourth the span. Required the fiber stress resulting from a moment from vertical loads of M inch-lbs.

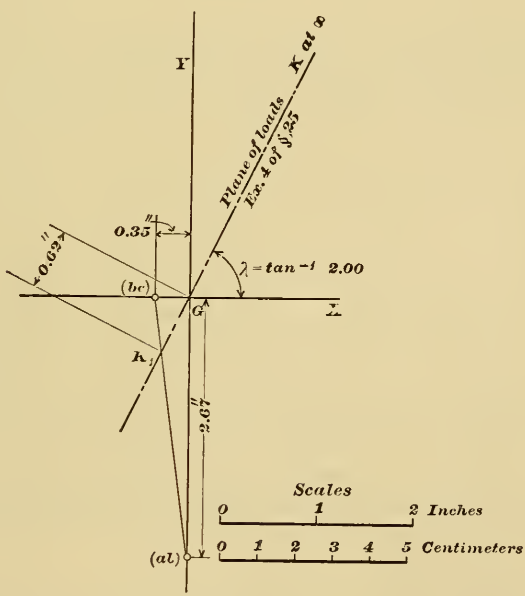


FIG. 19.

*Solution.* The construction of the side (ab) (bc) of the kernel will give the required $k_1$ and $k_2$.

$I_x = 56.9$ in.$^4$; $I_y = 3.78$ in.$^4$; $Z_{xy} = 0$.

By (24) and (25), as $A = 5.33$ in.$^2$,

(x, y) for (ab), $v_0$ being half the depth of the beam, or 4.0 in.

$$x = -\frac{0}{5.33 \times 4.0} = 0$$

$$y = -\frac{56.9}{5.33 \times 4.0} = -2.67 \text{ in.}$$

(x, y) for (bc), $v_0$ being half the flange width of the beam, or 2.0 in.

$$x = -\frac{3.78}{5.33 \times 2.0} = 0.35 \text{ in.}$$

$$y = -\frac{0}{5.33 \times 2.0} = 0$$

Plotting these co-ordinates in Fig. 19, outline of beam being unnecessary, $K_1$ is located and $k_1 = k_2$ scaled 0.62 in. By (23a), as before,

$$f' = -f'' = \frac{M}{5.33 \times 0.62} = \frac{M}{3.305} = 0.303 \text{ M. Ans.}$$

which agrees acceptably with result for same problem in Sections 13 and 28.

It may be worth while, in passing, to call attention to the sensitiveness of these rolled shapes to changes in the roof slope, as shown by the sharp variations in the kernel radii.

*26. Resistance Polygon.* The kernel is a polygon drawn to the same scale as the section of the bar. Its chief interest from our present point of view lies in the fact that any two continuous radii vectores are lengths representing the resistance moduli* (called also section moduli) of the section pertaining to the plane of loading whose trace contains these two radii. The area of reference by which these lengths must be multiplied to yield the third-degree quantities, the resistance moduli, is the area of the section, as is evident from a glance at equations (22), (23) and (23a).

Professor Land has pointed out† a small, but decided, gain in the ease, as well as accuracy of computation resulting from the substitution of the unit area for A as the area of reference. The resulting polygon is merely the kernel drawn to an enlarged and specially selected scale, and, of course, it retains the kernel's properties as a diagram of resistance moduli. Since its distinguishing feature is the more convenient representation of the resistance moduli, it can appropriately be called the resistance polygon for the section. The kernel can always be constructed from it by drawing a figure to $\frac{1}{A}$th its scale.

The writer believes that the publication of the co-ordinates of the apices of the resistance polygons for the various standard rolled sections would be the cheapest and most effective way of filling out the gap now existing in the manufacturers' tables of properties of rolled shapes. The addition is most needed for Z-bars; next in importance are angles. On the other hand, the co-ordinates

---

*These are $\frac{I_u}{y_1 \sin \beta}$ and $\frac{I_u}{y_2 \sin \beta}$ of equation (10a), or $\frac{I}{y_1}$ and $\frac{I}{y_2}$ of equation (10e).

†Zeitschrift des Vereines deutscher Ingenieure, 1898, p. 445. Hütte Taschenbuch, 17te Aufl. I, p. 345.

are readily computed for I-beams, channels and T-bars from data now given in the tables. It is to be hoped that the values of $Z_{xy}$ which would be needed for the computation of the co-ordinates of resistance polygons for angles and Z-bars would not be withheld.

*27. Equations for Use with the Resistance Polygon.* Calling $p_1$ and $p_2$ the two radii vectores of the resistance polygon coinciding respectively with $k_1$ and $k_2$ of the kernel, $p_1$ and $p_2$, measured in the proper scale, will be numerically equivalent to $Ak_1$ and $Ak_2$ respectively. Substituting accordingly in (22) and (23a) there result

$$f' = \frac{N}{A} + \frac{N\,q'}{p_1};\ f'' = \frac{N}{A} - \frac{N\,q'}{p_2}. \quad . \quad . \quad . \quad . \quad . \quad . \qquad 22')$$

$$f' = \frac{M}{p_1};\ f'' = -\frac{M}{p_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad 23'a)$$

If $u_s$ and $v_s$ be the co-ordinates of an apex S of the resistance polygon corresponding to a given tangent to the section, we have as modifications of (24) and (25), $u_s$ and $v_s$ being $Au_k$ and $Av_k$ respectively,

$$v_s = -\frac{I_u}{v_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad 24')$$

$$u_s = -\frac{Z_{uv}}{v_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad 25')$$

If any area, n, other than the unit be taken as area of reference $p_1$, $p_2$ and $v_0$ would each appear in these equations with n as a co-efficient.

*28. Examples of the Determination and Use of the Resistance Polygon.* It is believed that, though the resistance polygon is merely a result of drawing the kernel to a special scale, a couple of numerical examples will make its advantages and methods of use plainer.

*Example 1.* Taking the $5'' \times 3\frac{1}{4}'' \times \frac{1}{2}''$ Z-bar of Fig. 17, the co-ordinates of the apices (ab) and (bc) of the resistance polygon corresponding to the tangents AB and BC would be, by (24′) and (25′) noting that the values of $v_0$ are $-3.0$ in. and $-2.5$ in. respectively

$$\text{for (ab)},\ x = -\frac{9.05}{-3.0} = 3.02 \text{ in}^3.,\ y = -\frac{10.05}{-3.0} = 3.35 \text{ in}^3.;$$

$$\text{for (bc)},\ x = -\frac{10.05}{-2.5} = 4.02 \text{ in}^3.,\ y = -\frac{19.19}{-2.5} = 7.68 \text{ in}^3.$$

The apex (cd) could then be found exactly as the corresponding apex was found for the kernel in Section 24, and the three remaining apices follow by symmetry.

Plotting the polygon,* taking conveniently the scale 1 in. = 1 in$^3$., examples 2 and 3 of Section 25 take the form

$$f' = -f'' = \frac{M}{7.51} = 0.133\ M$$

$$\text{and } f' = -f'' = \frac{M'}{2.89} = 0.346\ M'$$

in which the 7.51 in.$^3$ and 2.89 in.$^3$ (or perhaps slightly more accurate values) are actually scaled as an equivalent number of inches from the resistance polygon.

Compare other solutions of these problems in Sections 12, 13, 15, 19 and 25.

2. An 8-in. 18-lb. I-beam acts as a purlin on a roof whose rise is one-fourth the span. Required the fiber stress from a moment of M inch-lbs. resulting from vertical loads.

*Solution.* With the aid of the handbooks, one finds the values of section modulus

$$R_x = 14.2 \text{ in.}^3; \ R_y = \frac{I_y}{\frac{1}{2} \times \text{flange width}} = \frac{3.78}{2} = 1.89 \text{ in.}^3$$

Then the co-ordinates of the four apices of the resistance polygon are, in inches$^3$ (0, 14.2), (1.89, 0), (0, — 14.2) and (— 1.89, 0). Plotting one side of this polygon in Fig. 20, the outline of the beam section not being needed, drawing GK, $p_1 = p_2$ are scaled and found to be 3.34 in.$^3$ Inserting this value in (23'a) we have

$$f' = -f'' = \frac{M}{3.34} = 0.300\ M. \quad \text{Ans.}$$

Compare other solutions of this problem in Sections 13 and 25.

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*29. Closing Remarks.* All the foregoing numerical examples concerning purlins were solved upon the usual assumption that the purlin is free to deflect in any direction. Thereby the effect of the whole roof covering as a stiffener in the plane of the roof is ignored. This effect might be considerable with some styles of roof covering, but would usually be difficult to estimate. A designer wishing to take it into consideration could do so by assuming a reasonable direction for the neutral axis instead of

*Or rather the parts of it which are needed, the side (de) (ef), and side from (ef) with slope of 1.190 (Section 24, 2). Apex (fa), as appears from Fig. 17, is not required.

calculating it from a given $\lambda$. He could also calculate $\lambda$ for his assumed $\alpha$ by

$$\text{ctn } \lambda = \frac{I_y \tan \alpha - Z_{xy}}{Z_{xy} \tan \alpha - I_x} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 26)$$

which is (14) rearranged, and then proceed as usual.

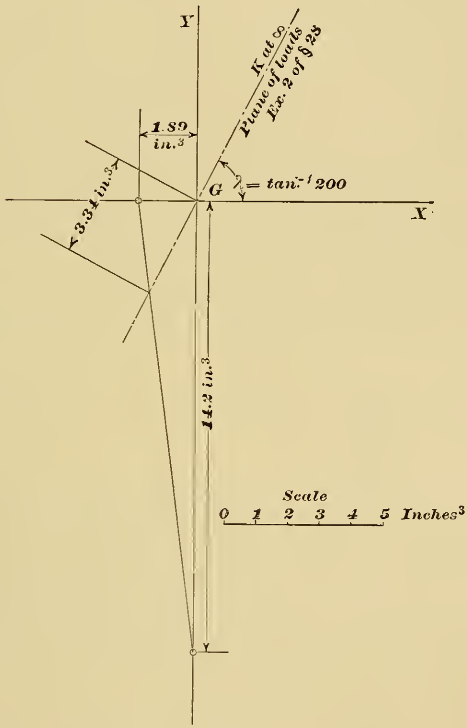


FIG. 20.

Effective tie-rods in the plane of the roof would cause $\alpha$ to vanish and modify stresses accordingly. The stress in such tie-rods could be determined by finding the force in their plane per running foot of the purlin, which would be required to combine with the given load to produce a resultant with such an inclination, $\lambda$, as to make $\alpha$ vanish.

# LIGHT MOUNTAIN RAILWAYS.

By George B. Francis, Member Boston Society of Civil Engineers.

[Read before the Society, May 14, 1902.*]

Having recently had occasion to render an opinion relating to the advisability of adopting narrow or standard gauge track for a railroad of light mountain character, together with an opinion on the question of grades and weight of rail, I took occasion to supplement my own opinion (which is unqualifiedly for standard gauge, and a rail as heavy as the finances of the projectors will permit, up to fifty pounds per yard) with the published opinions of others, and also to compile a reference list covering the location of such information, together with a statement of the data regarding the gauge, grade, curvature and weight of rail on quite a number of existing railroads of this character.

Believing such a compilation of references and facts would prove of value to the profession, the same is herewith set forth as a contribution to the papers of the society, together with my opinion about the subject.

It is my firm belief that the standard (4 feet 8½ inches) gauge railway can be built and operated (with proper equipment) wherever it is possible to construct a narrow gauge road, at practically the same cost for all of the constructive features, and on practically the same alignment and grades, thus obtaining the advantages of forwarding cars, where connection is made with the universal gauge, without transferring, having cars of greater capacity for the road in question and obtaining the advantage of wider fire boxes for locomotives used on the usually steeper grades of mountain railways.

In regard to the weight of rails to be used a reference to "Wellington's Railway Location," chapter 22, page 737, will speedily convince the most skeptical that it is very easy to waste money in the purchase of the lighter sections, as the elements to be purchased are not directly proportional to the weight of the rail.

The first element, stiffness, varies as the square of the weight per yard, consequently if the weight is increased 50 per cent. the stiffness is increased 125 per cent., and if the weight is doubled the stiffness is increased 300 per cent. Or stated another way, a 40-pound rail is four times as stiff as a 20-pound rail, thus for

*Manuscript received May 17, 1902.—Secretary, Ass'n of Eng. Socs.

twice the cost we get four times the value in one essential element.

The strength is also increased in a greater ratio than the weight, while the durability or wear is many times greater in the heavier sections than the lighter.

The sharpness of curvature possible with the standard gauge track is illustrated on every hand in the street railway service, where the radius varies from 35 feet up, and the locality is inconceivable where it is not possible to get a much greater radius than this in mountain railways.

Nearly all standard gauge freight car equipment will pass around curves of 50 feet radius when the curves are properly guarded and the cars are run singly and it is always possible to introduce long couplings if the radii requires them. The wheel base on street railway cars using standard gauge and curvature as sharp as 35 feet radius varies from 4 to 7 feet.

Comparative features of various existing light or mountain railways with references:

| Name. | Gauge. | Weight of Rail Lbs. Yd. | Curve Min. Rad. | Grades Max. ft. per 100. | |
|---|---|---|---|---|---|
| Northwestern Pennsylvania Lumber Railways | 4′ 8½″ | 40 | 303′ | 3.32 | a |
| Dublin and Wrightsville Railroad, Georgia | 4′ 8½″ | 40–45 | 955′ | | b |
| Atchison, Topeka and Santa Fé, over Raton Mountains | 4′ 8½″ | | 359′ | 6.00 | c |
| Light Mountain Railroad, Columbia. | 3′ 0″ | 35 | 146′ | 5.00 | d |
| *Silver Bow Railroad, Butte, Mont. | 4′ 8½″ | 52 | 64′ | 6.00–7.50 | e |
| The Tamalipais Mountain Railway, California | Narrow. | | 72′ | 5.00–7.00 | f |
| Georgetown Loop, Colorado, Union Pacific, Denver and Gulf Railway. | 4′ 0″ | | 191′ | 3.50 | g |
| Salt Lake and Mercur Railroad | 4′ 8½″ | 35 | 146′ | 4.20 | h |
| Utah Central | Narrow. | | 288′ | 7.25 | i |
| Alta Branch, Rio Grande Western | | | | 5.00 | j |
| Guatemala Northern Railway | 3′ 0″ | 40–56 | | 3.00 | k |
| Guatemala Central Railway | | 54 | 383′ | 3.00 | l |
| Denver and Rio Grande Railroad, Colorado | 4′ 8½″ | 30–85 | 288′ | 3.00 | m |
| Madison Incline, Pittsburg, Cincinnati, Chicago and St. Louis Railway | 4′ 8½″ | | | 5.90 | n |
| Canadian Pacific Railway | 4′ 8½″ | | | 4.49 | o |
| Great Northern Railway | 4′ 8½″ | | | 2.20 | p |
| Northern Pacific Railway | 4′ 8½″ | | | 2.20 | q |
| Union Pacific Railway | 4′ 8½″ | | | 2.20 | r |

*This is an electric railway. All others referred to use steam for motive power.

| Name. | Gauge. | Weight of Rail Lbs. Yd. | Curve Min. Rad. | Grades Max. ft. per 100. |
|---|---|---|---|---|
| Atchison, Topeka and Santa Fé Railway, main line ............ | 4′ 8½″ | | | 3.40 s |
| San Francisco and Portland ....... | 4′ 8½″ | | | 3.30 t |
| Great Northern Switch-back ...... | 4′ 8½″ | | 442′ | 4.00 |
| Northern Pacific Switch-back ..... | 4′ 8½″ | | | 5.60 |
| Denver and Rio Grande Railroad, Calumet Branch.................. | | | | 7.00 u |
| Denver and Rio Grande Railroad. .. | Narrow. | | 240′ | 4.00 v |
| Colorado Midland Railway ........ | 4′ 8½″ | | 288′ | 4.00 w |
| Denver, Leadville and Gunnison Railway ...................... | 3′ 0″ | | 288′ | 4.00 x |

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b. The Cheapest Railroad in the World, by Arthur Pew, *Trans. Am. Soc. C. E.,* Vol. 23, p. 111.

c. The Atchison, Topeka and Santa Fé Railroad over Raton Mountains, by James D. Burr, *Trans. Am. Soc. C. E.,* Vol. 8, p. 295.

d. Light Mountain Railroad, Columbia, by E. J. Chibas, *Trans. Am. Soc. C. E.,* Vol. 36, p. 65.

e. Silver Bow Railroad, Electric, by F. W. Blackford, Jour. Assn. Eng. Socs., Vol. 22, p. 28.

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i. Utah Central Railroad, *Eng. News,* July 2, 1896.

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The Economic Theory of the Location of Railways, by Arthur Wellington, chapter 22, p. 737.

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The Economic Theory of the Location of Railways, by Arthur Wellington, pp. 751 to 754 inclusive.

Railway Track and Track Work, by E. E. R. Tratman, p. 351.

Railway Track and Track Work, by E. E. R. Tratman, p. 359.

Light Railways, by A. C. Paine, *Eng. News,* June 29, 1899, p. 421; also discussion, last paragraph, p. 421; also Mountain Railways, by C. A. W. Pownal, last two paragraphs.

The Economics of Railway Location (editorial), *Eng. News,* April, 20, 1899, p. 248.

*Eng. News,* April 6, 1899, p. 210, second paragraph.

*Eng. News,* Oct. 15, 1896, p. 242, first paragraph.

In connection with this data on light mountain railways it may be interesting to recite some features about gauge, curvature and grades of the extensive railroads built and under way in Africa.

Without a doubt Africa is the next continent which is to be brought into civilized condition, and to be rescued from ignorance and superstition and therefore, through development within the next two hundred years, to become a large factor in the world's progress.

Transportation is of course the one prime necessity which will bring this about. The gauge of 3 feet 6 inches appears to be destined to become the standard gauge of the continent.

The Rhodesian system of railways in South Africa now amounts to about 2000 miles of 3-foot 6-inch gauge, laid with 60-pound rail. The railroad now reaches a point 1500 miles north from Cape Town.

The Sudan Government railways, comprising two lines, both starting at Wadi Halfa, on the River Nile, and stretching southerly, one up the valley of the Nile to Kerma, a distance of 203 miles; the other for 230 miles over the Nubian Desert to Abu Hamed and then up the valley of the Nile to Khartoum, which is 576 miles from Wadi Halfa, making a total of 779 miles of a 3-foot 6-inch gauge. The weight of rails on the former, or Kerma line, varies: some 36 pounds, some 41¼ pounds and some 50 pounds per yard; the gradients as sharp as 1 in 60 and minimum curvature of 500 feet radius. For a distance of 66 miles on one part of this road there is scarcely a bit of level or straight line. The weight of rails on the latter, or Khartoum line, are 50 pounds per yard; the sharpest gradient 1 in 120 and minimum radius of curve 955 feet. This road is destined, according to the statement of Sir Douglas Fox, to form in part the foundation in the future of the Cape to Cairo Railway. They were, however, built as a military necessity and for that purpose only.

The Uganda Railway which has a meter gauge, gradient of 1 in 30 and curves of 400-feet radius on some temporary parts of the line, starts from Mombasa on the Indian Ocean and reaches to Lake Victoria Nyanza, a distance of about 600 miles. The highest point on this line is 8323 feet above sea level. This road is laid with steel ties.

In Australia there is a most regretable state of affairs regarding the gauge of the Government railways, and what the future will be it is hard to say. Great inconvenience and loss exists in the transportation of goods. The condition is as follows:

Out of a total of 12,554 miles there are 3725 miles of 5 feet 3 inches, or the Irish gauge; 2811 miles of 4 feet 8½ inches, or the English and United States gauge; 5970 miles of 3 feet 6 inches, or the African gauge; 48 miles of 2-foot 6-inch gauge. There are also 1000 miles of private railways of 3-foot 6-inch gauge.

Victoria is the only colony which has held fast to the original choice of gauge, viz., 5 feet 3 inches.

Tenders were invited in two instances on construction for both 5-foot 3-inch gauge and 3-foot 6-inch gauge, the result being that the narrow gauge showed a saving of $750 in one case and $900 in the other case per mile.

There are many grades on the Australian lines of 1 in 30 and 1 in 45 and 1 in 50.

The capitals of the four principal Australian states are connected by a railway 1783 miles long, over which the interstate express trains travel. Starting from Adelaide, 150 feet above sea level, the line has a rise of 1615 feet in 20 miles, then a descent for 40 miles after which it rises to about 1000 feet above sea level, then up and down with a summit level of 1940 feet, then descending 987 in 11 miles to Melbourne at sea level.

The gauge for 672 miles has been 5 feet 3 inches and now changes to 4 feet 8½ inches, again the summit level becomes 2400 feet above the sea; there is also a fall of 1488 feet in 16 miles, thence to Sydney, which is at sea level and 1061 miles from Adelaide. Leaving Sydney, in 36 miles the road rises and falls about 650 feet to the Hawkesbury bridge, afterward crossing the coast range a fifth time at a level of 2073 feet above the sea. The summit of the entire line is, at Ben Lomond, 4473 feet above the sea. At the Queensland border the gauge changes to 3 feet 6 inches, the line then falls 1524 feet, rises again 2003 feet, thence descending to Brisbane, 1783 miles from Adelaide.

This brief description of the Capital line is given to illustrate the inconvenience of gauge and the mountainous character of the road.

In Queensland, curves of 330 feet radius are frequently used. All late rails are of the common T pattern, varying from 60 to 100 pounds per yard.

The information here given relating to the African and Australian railways is extracted from more voluminous papers, presented at the International Engineering Congress, held at the University, Glasgow, on the 3d, 4th and 5th of September, 1901, Proceedings of Section 1 Railways, and published by Wm. Clowes & Sons, Lim., 32 Cockspur Street, London, S. W., 1902.

The chairman of the meeting (at which the paper of Prof. W. C. Kernot on Australian Railways was presented), Mr. B. Hall Blyth, M.I.C.E., commented on the Australian gauge question as follows:

"It seems to me that the point of greatest interest is that which has caused anxiety over and over again in this and other countries, namely, the break of gauge. It was settled long ago in this country, and it seems to me that that author's view is that it would have been better for Australia if they could have come to some arrangement for a uniform gauge in that country. The question is not altogether an abstract one now, because it is arising every day in this country in connection with light railways. A great many advocates of light railways think that they would be more profitable if a narrower gauge than the 4 feet 8½ inches were adopted. No doubt, from an engineering point of view, they could be more cheaply constructed, but if an estimate is made out for a narrow-gauge light railway and compared with that for the 4-foot 8½-inch gauge, it will be found that the saving in construction will be more than counterbalanced by the difficulty and inconvenience that will occur in transferring goods from the narrow to the broad gauge. That is the almost universal opinion of railway managers, whether it is or not of the railway engineers. Of course, there are isolated cases in which it would be almost impossible, except at enormous cost, to construct a broad-gauge line, and therefore the narrow gauge must be adopted; but I am satisfied that in light railways it would be far better to adhere to the ordinary gauge, so that they can connect at one end or the other with the existing lines of railway."

A system of light railway in Egypt, designed to form feeders to main lines, is described by J. A. W. Peacock, Chief Engineer, in the minutes of Proceedings of the Institute of Civil Engineers, Vol. 145, August, 1901. The lines are laid in Provinces of the Nile Delta and consist of about 500 miles of track of 2-foot 5½-inch gauge, rail sections of 30 pounds per yard. The minimum

radius is 221 feet, excepting at stations where it is fixed at 82½ feet. The rails are laid along the highways and the cost has been about $10,000 per mile.

In the same volume, page 359, it is stated that the Trans-Siberian Railway is of 5-foot gauge and is laid with 54-pound rails; also in the same volume the Nilgiri Mountain Railway is described by W. J. Weightman, M.I.C.E. The gauge is 3 feet 3⅜ inches and references are also made regarding gauge, curves and grades to several other foreign mountain railroads.

## BITUMINOUS MACADAM PAVEMENTS.

By William H. Burns, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, May 27, 1902.*]

The principle involved in the bituminous macadam construction contemplates the combination of relatively coarse and fine mineral grains in such a way as to have in themselves a firmness sufficient to sustain the weight of traffic. The bituminous cement, supported and held in place by the particles of stone, is used solely to protect the stone from the action of water and weather, to bind the mineral particles together sufficiently to prevent abrasion from traffic at all atmospheric temperatures and to provide an elastic cement or cushion between the mineral particles which will deaden the jar and prevent the wearing which would result from any movement of the integral parts.

The principles on which this pavement is built are exactly the reverse of those used in asphalt construction. The asphalt surface consists of an asphaltic mortar; the grains of sand, which in themselves have no firmness to sustain traffic, being supported by the bituminous cement, forming a mastic or mortar that will at all atmospheric temperatures sustain traffic and resist abrasion. Asphalt is a bituminous mortar pavement (bitumen and sand). Bituminous macadam is a bituminous concrete (bitumen, sand and hard stone). Asphalt is usually laid on a concrete base; bituminous macadam on a foundation of crushed stone.

The practical use of millions of square yards of macadam roads and of a few miles of asphalt pavement has fully demonstrated that a well-rolled crushed stone foundation will stand the pressure of traffic. The two oldest asphalt pavements in this country are laid on this class of foundation, notwithstanding that, at the time of their laying, proper rolling, as practiced to-day, was not in vogue. The only function of the concrete foundation is to sustain the weight of the load, and its utility in this requirement cannot be questioned. It fails to aid in holding the wearing surface in place, as it presents a smooth surface, causing tendency of the wearing surface to shift. It fails to offer proper drainage under the pavement, and, on the contrary, is a trap for moisture, which is always an important factor in subsurface construction. In an asphalt pavement the moisture thus held often causes disintegration or rotting from the base upward. It should be used

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only in cases of very poor soil or other conditions affording a weak subformation.

The method ordinarily employed in the construction of bituminous macadam is to assume that a natural foundation, thoroughly rolled with a heavy road roller, furnishes a solid subbase; that a solid base of 4 to 6 inches of 2 to 2½-inch stone will, after thorough compression with a 15 to 20-ton roller, provide an ideal foundation for a waterproof surface, and will provide drainage to moisture accumulating from the surrounding ground. If more drainage is necessary, drains, rather than extra foundations, are advisable. The stone is better if very hard; but this is not so important in the foundation as in the top.

On top of the stone foundation is spread or sprinkled a coating of specially prepared thin bituminous cement, which enters the minute crevices of the surface of the stone and permits the stone in the foundation to be firmly held together with the waterproof cement which is afterward freely used over the surface of the foundation. This waterproof cement is thus enabled to grip onto the stone permanently, and, being of a hard, pitchy nature, of a grade of flexibility that will bind the surface of the foundation firmly in place, it makes the foundation itself rigid before the wearing surface is rolled in.

On top of the foundation thus prepared is spread a layer of the wearing mixture, which should have a thickness of about 2 inches after its maximum compression. This mixture is a carefully prepared combination of 1 to 2-inch stone, having voids filled with receding sizes to a dust or powder of stone. Some sand may be used to aid in filling voids when necessary.

The large stones for use in the wearing surface, as well as the fine stone in receding sizes, should be from a sound, hard rock least subject to wear by abrasion. Of course, the locality, quality, condition of traffic and cost will be controlling features in the selection.

The mineral or stone part is dried and heated in a modern drier, and is then separated, by screening with a rotary screen, into sizes varying from fine dust, which is less than 0.005 inch in diameter, to the largest size used. The several sizes of stone are then mixed in predetermined proportions, so as to reduce the voids to about 10 per cent., in a modern "twin pug" steam-power mixer, and the hot bituminous cement is added in the mixer, not only in sufficient quantity to coat every particle and fill all of the remaining voids, but with enough surplus to furnish to the mixture, after compression, a rubbery and slightly flexible condition.

The mixer makes seventy-five revolutions per minute, and every particle of mineral is coated in about fifteen seconds, but the mixing is continued about two minutes, to provide absolute uniformity of distribution of bitumen and mineral. The whole is dumped by gravity into wagons and hauled to the street, where it is spread in the same manner as an asphalt pavement. It is then rolled with a 15 to 20-ton road roller, which gives many times as much compression to the inch run as the ordinary asphalt roller. After a thorough and continuous rolling, there is a little honeycombed appearance on the surface, where coated particles of stone come together, but the body of the mixture, on being broken, is seen under the magnifying glass to be unusually dense.

Good rolling is an essential feature, as it assists to place the particles where they belong, and continued rolling forces out the minute air bubbles and forces the surplus bitumen into the fine voids, leaving the body of the surface so dense that it cannot be rutted or displaced by traffic. It also adds to the life of the bituminous cement by protecting it from the action of exposure to the elements in minute semidetached particles. The rolling should commence as soon as the surface is spread, and it is advisable that one heavy roller should not be required to do more than 1000 square yards of surface per day.

Great care should be exercised in heating the stone or mineral parts, as overheating the stone will cause rapid change in the softness or ductility of bituminous cement, each particle of stone being coated with a layer of less than 0.002 inch in thickness. In this condition of exposure high temperatures act very rapidly on the cement. This condition is not so important as in the asphalt pavement, as the coating of the cement is heavier and it is used in a softer form, and, therefore, has more life to lose before it becomes inefficient. It is, nevertheless, important, for the cement is prepared with an allowance made for the normal change in making the pavement, and, if the change is abnormal, the physical differences may effect the life of the work.

On top of the surface thus made there is poured and rubbed into it all of the quick-drying bituminous cement that it will take, partly to seal the surface from attack and partly to hold and help make a practical wearing surface. This leaves the surface as sticky as if freshly painted.

On this surface is spread a coat of fine stone chips, which adhere to the bitumen on the bottom and present a rough, gritty surface to travel. The rolling of these rough chips into the surface has the effect of putting the pavement under greater pressure,

and forces as much stone into the surface as it can possibly receive, thus making it more gritty and suitable for travel.

In resurfacing macadam the surface should be roughened, and on resurfacing other forms of relatively smooth pavements an intermediate or binder layer of coarse stone and hard bitumen should be used to hold the surface firmly in place.

The above method gives an ideal road surface, and, with traffic and wear, it will always maintain a large part of the roughness of a perfect macadam road, as compared with the smoother and polished surface of the asphalt. It is relatively as smooth as asphalt, yet the coarse particles of the surface hold moisture and dust longer, and the pavement will always be less slippery and less dusty, and can be made more durable than any bituminous pavement previously laid. Under considerable traffic it is as durable as a block stone pavement made of the same stone. While the coarse stone in the pavements prevents cutting up of the bitumen under traffic in summer, the larger amount of bitumen used, as compared with the voids to be filled, provides a surface more elastic and not as hard on horses while fully as pleasing for pleasure driving.

The click from the horses' hoofs is much less than with asphalt, and the pavement is one of the most noiseless in use. This is specially noticeable in cold weather, when all bituminous pavements are the hardest and most resonant.

From the practical standpoint of the engineer it can readily be seen that the rigid stone particles permit of: (a) the reduction of voids; (b) the use of a softer bituminous cement; (c) a heavier coating of cement around each grain.

Each of these self-evident conditions will in itself more than double the life and service of the bitumen itself. If the pavement fails, it will be from causes other than those to which is due the failure of asphalt pavements as at present constructed, but might be from such causes as the following: (a) the crushing or grinding of a poor quality of stone under traffic; (b) carelessness in not properly placing the various-sized elements of stone; (c) improper equipment and supervision induced by a straining after economy.

Bitumens of certain grades have been known to remain plastic and intact for more than twenty centuries. It would be impossible except in a dense mixture. It is also a fact, but one not generally known, that, so long as the bitumen remains plastic, there is no perceptible wear from abrasion, and that the wear of a bitumen can take place only when it becomes hard and passes beyond a plastic state at low atmospheric temperatures, when it becomes

brittle and crumbles. Some forms of bitumen may also lose their viscosity, plasticity and ductility by the action of water in dissolving salts contained in it. In liquid state bitumen has little or no plasticity.

The selection and method of preparation of bituminous cement has naturally great relation to the life of any pavement. Bitumen, as is well known, passes by almost insensible degrees from the liquid to the solid form, and may be tempered to any consistency. The softer the temper of any given quality of bitumen, the longer its life under any given exposure. The softer the temper of the cement, the lower the melting point and the greater its flexibility at any temperature lower than its melting point. The length of time any given grade of bitumen will remain flexible and fill its office depends largely, if not wholly, upon the kind and condition of exposure.

It does not depend upon traffic, as is generally supposed, except that, in imperfect mixtures containing many voids, a certain amount of traffic is essential to keep an enamel on the surface, which alone protects the bitumen in the body from attack in such minute sections that failure would otherwise occur much easier. With certain forms of bitumen which, in their natural state, contain soluble salts, the pavement, if it is kept wet, cannot provide the enamel; and the traffic which, on a dry pavement, would add to its life simply rubs off the disintegrating surface and causes its early destruction.

With natural hard bitumens or pitches, the process is to "cut back" the natural material with oil of various classes, in order to produce the softness desired. With natural soft bitumen the process is to extract a part of the natural softening oil. All other things being equal, the process of cutting back the bitumen injures its physical quality. With some forms of bitumen, however, it may be advisable to substitute a good permanent oil or softening flux for an inferior oil present in nature. The general practice in "cut back" cements is to remove an oil of great value commercially, and of value to the cement, and to substitute an inferior oil of little commercial value. It is seldom that any crude bitumen, as it is found in nature, is in the best state of flexibility for use for any purpose. It is sometimes used in its crude commercial state, but it is generally deficient in some one or more essential properties.

For testing bituminous cements or mixtures there are no established methods generally available and recognized by engineers. Unless the engineer has had practical and extended ex-

perience in the manufacture, use and testing of bituminous materials, his only safe method of getting good work is to specify what is wanted in such detail that, in some direct or indirect way, it carries with it the use of one or more good, established materials as used by an experienced party or parties.

It is unfortunately true that the experts are few and far between, and that the amount of fair competition which is desirable to the engineer in bituminous materials or work is often difficult to obtain. This is largely due to the fact that the business has been developed in secrecy by interested parties, who are generally manufacturers or contractors, and have frequently never themselves studied the matter scientifically, and whose success depends solely on having happened to strike a combination or mixture which gives greater success than the mixture of some competitor. Under these conditions the engineer is often led to believe that "white is black and black is white," and he often attributes the success to the quality of the material used, when it is properly attributable to the method of its use or the intelligence and experience of the user or manufacturer. It is safe to say that almost every initial failure in the use of any bituminous material is due almost entirely to the method of use, for hardly any crude bitumen is so poor that it cannot be made into a cement under proper treatment so that it will appear for a time almost equal to the very best that could be produced. So sensitive are the bitumens to improper treatment that a relatively poor bitumen, owing to more intelligent treatment, often proves better in the completed work than the better grade used under haphazard or unscientific methods.

This pavement has been laid in Pawtucket, R. I.; Holyoke, New Bedford, Cambridge, Lowell and Brockton, Mass.; Salem, N. J., and Charleston, S. C.

Harvey Street, in Pawtucket, is laid on a 12½ per cent. grade. These pavements have successfully withstood extremes of temperature during the summer and winter.

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## TELPHERAGE.

By CHARLES M. CLARK.

[Read before the Civil Engineers' Club of Cleveland, April 22, 1902.*]

*Definition.* Telpherage is derived from two Greek words "τελε" and "φερω." "Tele" means far, and "ferro" means to bear or to carry. Therefore, telpherage means far-carrying. The same word "tele" appears in telegraph and telephone. The word was originally invented by the late Professor Fleeming Jenkin, who was the early spirit of telpherage, and but for his untimely death, telpherage would be even more extensively used. Like many other words, its meaning has varied. In the beginning it meant, practically, aerial electrical transportation, but now it has been brought back to its original meaning, which is the transportation of material to a distance by electricity, overhead, or sometimes on the surface, or even underground. In the latter case, it is termed "tubular despatch." Therefore, telpherage may be concisely defined as the electrical transportation of material. The method of applying it is an engineering problem and must depend upon local conditions, and even to-day the term "telpherage engineering" is becoming a common expression. It will be noticed that the word "automatic" is left out in these definitions. The reason for this is that it is a commercial question, and in cases where a man is required to attend to certain portions of the work, it is often cheaper for the man to go with the load than to use automatic devices. As to whether it is better to make an installation automatic or otherwise, depends entirely upon the comparative cost of the

*Manuscript received May 9, 1902.—Secretary, Ass'n of Eng. Socs.

two methods of operation. In this connection it may be said that with telpherage plants the word "telpherman" is now often used.

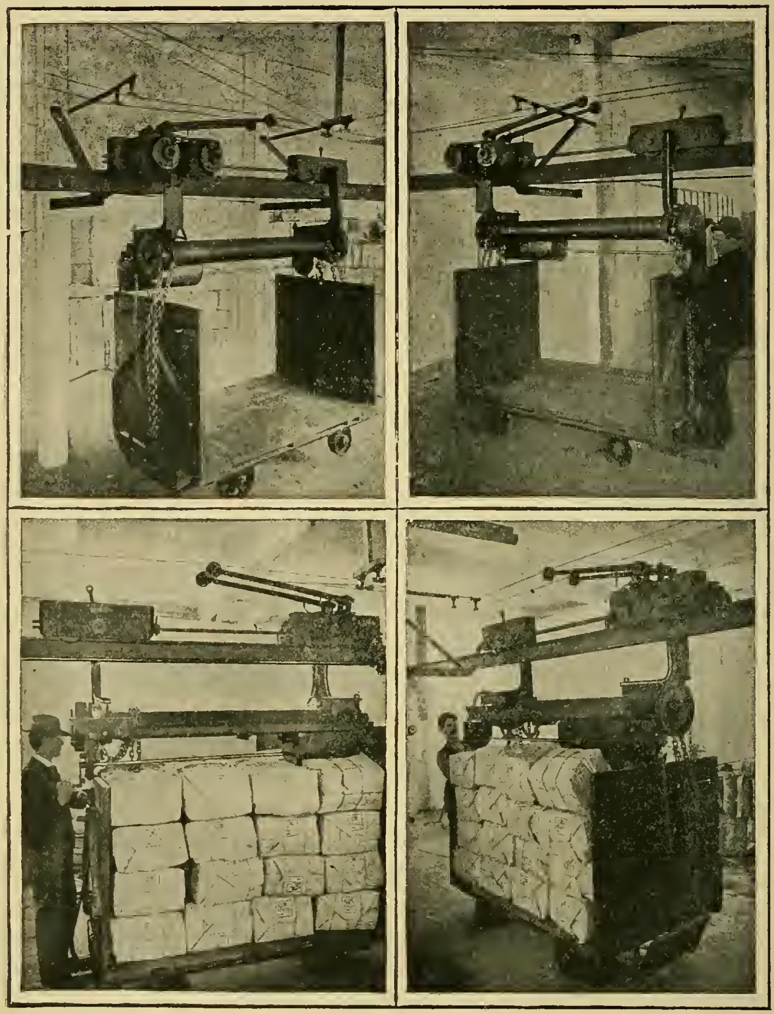


FIG. 1. Side bearing telphers with permanently attached trailer. Track solid rail. Telpher controlled from either end. Length 1,200 feet. Four curves one "S" curve. Grade 12 per cent. Maximum total 4,000 lbs. Speed on level 10 miles per hour. Speed on grade 5 miles per hour Horse power—5 horse power. Capacity, 100 tons per day per telpher.

*History.* The early history of telpherage closely resembles that of the electric railway. Before the successful pioneers in electric street railway traction had finally accomplished satisfactory results, many men had experimented, and it is well known that, some forty years ago, an electric railway was operated, having a speed of several miles per hour. It seems that it is necessary, with all successful applications of power to the transportation problem, that much preliminary work, seemingly unproductive, must be done. It often happens, as in the case of early telpherage, that the time was not ripe for its commercial adaptation. In the history of telpherage in England, a telpherage line was installed, using what was then called the series system, whereby it was necessary to use a telpher with a number of trailers. One section was positive and the next negative, the current passing from one section of the track to

FIG. 2. Track of above showing "S" curve.

the other through the motor, thereby completing the cricuit. In passing over the insulator between the positive and the negative sections, there necessarily occurred considerable sparking, which greatly increased the cost of maintenance. It was also necessary always to have trains of certain lengths. There were many other disadvantages, such as having to use a track made of round bar rail and the difficulty of manufacturing reliable electric motors. If it was desired to install a telpherage plant, it was always necessary to put in an engine, boiler and dynamo. In comparison with its early history, telpherage to-day possesses the advantage that every factory, where there is need for tel-

pherage, either has its own electrical plant, or the power may be rented from existing central stations or even street railway stations. There are also to-day for aerial transportation most excellent cables made especially for telpherage work, and likewise, where it is more desirable to use than solid rail cable, special shapes have been devised which give most excellent results. Motors, controllers and carriers of great reliability are now manufactured following the methods developed by the best railroad practice.

Before it was decided to enter into the present commercial adaptation of telpherage, an engineer visited all the electrical manufacturing plants and electrical installations in Europe, and found that nothing was being done in the transportation of material electrically. In the United States many experiments had been made, but the inventors were always seeking the unobtainable. Upon careful research, it was found that there were 450 patents directly applying to telpherage and several hundred more which pertained indirectly to this subject. Most of these original inventors, were, however, too ambitious, and there was hardly any limit to the number of miles per minute which was to be achieved by the new and wonderful agent, electricity. Not only material was to be transported, but also passengers, and beautiful cars of mahogany were built and put in experimental operation. Cigar-shaped carriers were devised, some of which made a speed of two miles per minute or more, and when it was impossible to attain a greater speed there was great discouragement. There are no authentic examples of much more than experimental work, namely, merely conveying material between two points, generally in a straight line, placed in some vacant lot or loft, and there seemed to be a desire to force the method of transportation according to certain preconceived ideas, rather than to pay the necessary attention to its commercial adaptation.

*Construction.* On account of various advantages in regard to the distribution of material—such as depositing at an elevation —most of the telpherage plants thus far installed, have been overhead. As engineers, you will be most interested in hearing what has been accomplished; the descriptions are, therefore, confined to overhead work. Under the head of construction, it may be stated that the track is made of cable, especially drawn, either of standard wire or lock coil type, which latter has a strength approximating 95 per cent. that of the solid bar, or else solid rail, either of flat, girder or bulb type.

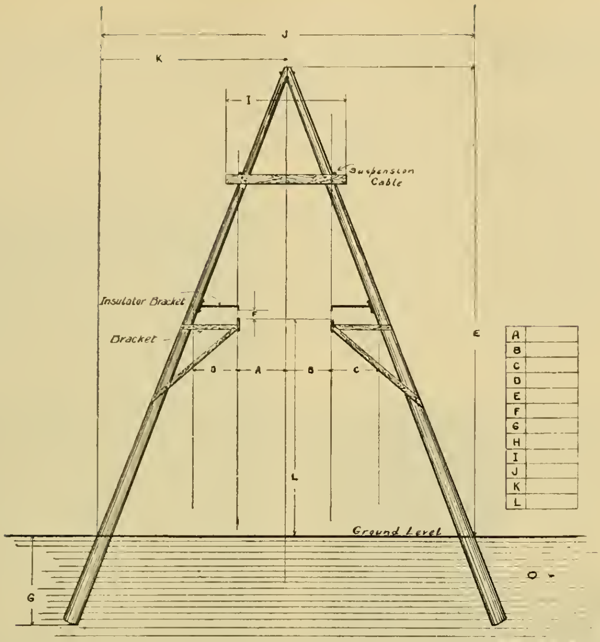



FIG. 3. SUPPORTING POLE, DOUBLE LINE. One of the simplest methods of pole construction for double lines. Especially recommended for long lines and where trees are available.

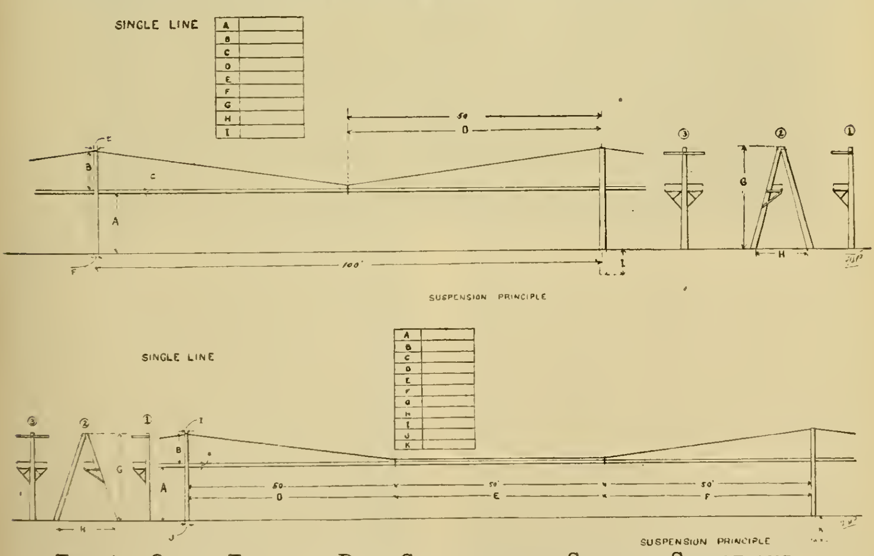



FIG. 4. OTHER FORMS OF POLE CONSTRUCTION, SHOWING SINGLE AND DOUBLE LINES. The track cables are supported by another cable, which is called the suspension cable. It would be impossible with long spans to stretch a cable so that under load there would not be considerable deflection. This deflection or sag is taken up by the suspension cable. Not only can we make the track cable horizontal, but even higher in the center than at the terminals.

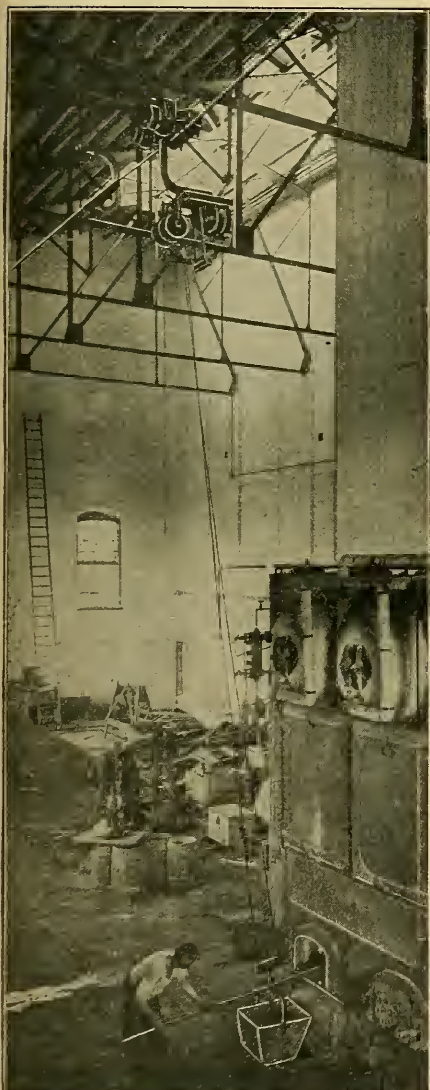
The cable tracks are supported every hundred feet, provided it is convenient to erect poles or structures. Where there are deep ravines or between upper stories of factories, the span is made to correspond with the distance, and may be made of any reasonable length. In addition to the track cable, upon which the telpher runs, there is also what is known as the suspension cable. As is well known, it would be impossible to prevent considerable sag in the track cable and therefore the track cable is suspended from this suspension cable by means of hangers. The number of these hangers depends upon the length of the span. It will be easily seen that it is possible to have the

Fig. 5. Cable construction, Pittsburgh, Pa., line 97 feet from the ground, illustrating suspension cable, track cable and hangers.

center of the span higher than the ends, by merely raising the suspension cable and the hanger. This obviates one of the early difficulties met in the use of cable for telpherage, as there is now no objectionable deflection in the cable when the telpher approaches a bracket. There are several methods of connecting the track and suspension cables by means of the hangers. The sizes of the cable, hangers and brackets vary, depending upon the weight which comes upon each individual span. The support is either simple poles with a bracket, or what is known as the "A" construction or ordinary cross bents. Cable con-

struction costs less than solid rail, except where there are many switches, in which cases the prices of solid rail and cable approach each other. In general, cable lines is recommended for straight lines, except where the weight is excessive.

In solid rail construction, the supports are ordinarily placed sixteen to twenty feet apart; longer spans are used if it is not convenient to erect supports. On long spans, the track consists of a girder rail with the track rail above it. It is not possible to give any general rule, as to what kind of track it is advisable to use, as this is a factor of the length of the spans and the



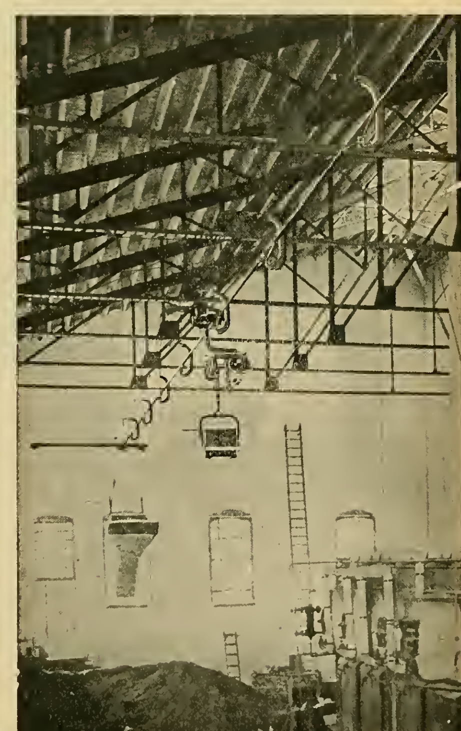


FIG. 6. Examples of cable construction with telpher, electric hoist and bucket, Elizabethport, N J.

weight. The weights conveyed thus far by telpherage vary from 125 to 10,000 lbs. and the cost varies accordingly. It will be readily understood that when the weights are greater, the supports must be nearer together, and the cables or girders heavier. Running parallel to the track rail, either above or at the side, depending upon the amount of head room, are stretched one or more trolley wires; one wire, if the track is used as a return. If, however, it is desired not to use the track as a return, or to use alternating current, two trolley wires are employed. There are many other details of construction, but the photographs and outline drawings will serve to illustrate better than any description.

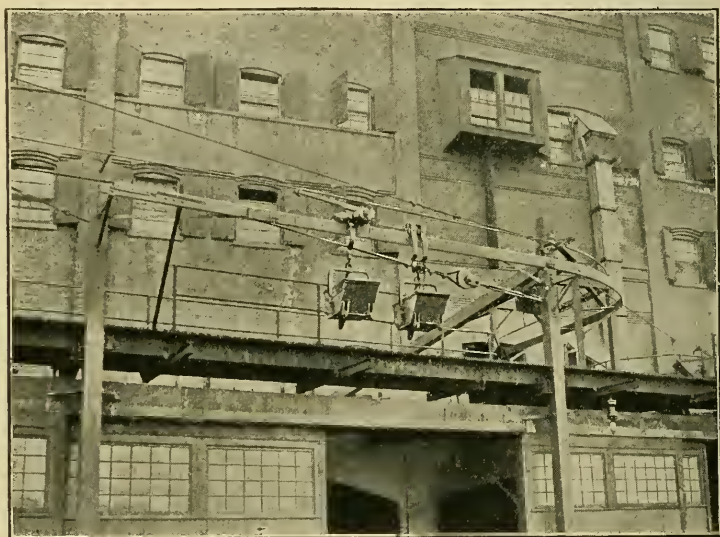


FIG. 7. Solid rail combined with cable construction. Capacity, 150,000 lbs. of ashes in ten hours. At present, handling the ash output of 23 boilers with other refuse. Average power consumed about one horse power. Located in New York City.

*Telphers.* According to the construction, telphers are divided into three distinct classes, center bearing, side bearing and alternate bearing. The center bearing has two motors, one on each side of the track; the side bearing has both motors on the same side, and the alternate has one motor upon one side of the track and the other motor upon the other side, but not upon the same shaft. Illustrations of each kind (Figs. 8, 9, 10, 11 and 12) are shown, also the same in operation. All the weight, in the side-bearing telpher, is utilized for traction, and the load is suspended

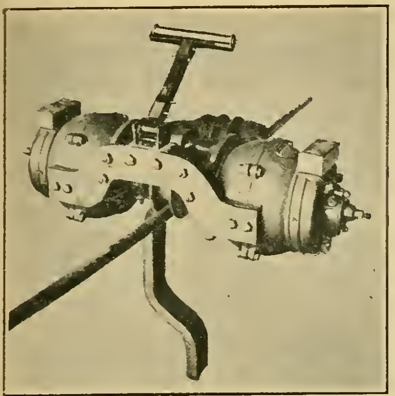


FIG. 8. CENTER-BEARING TELPHER.

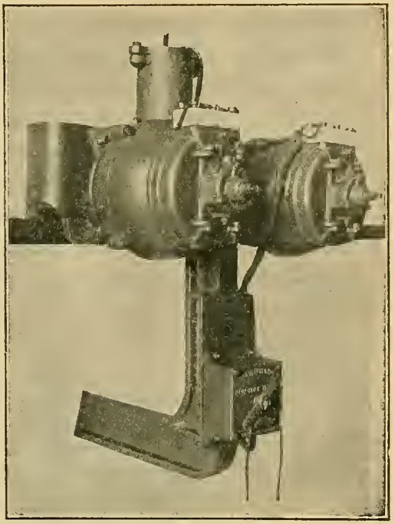


FIG. 9. TELPHER WITH SOLENOID SPEED REGULATOR FOR GRADES AND REVERSING SWITCH.

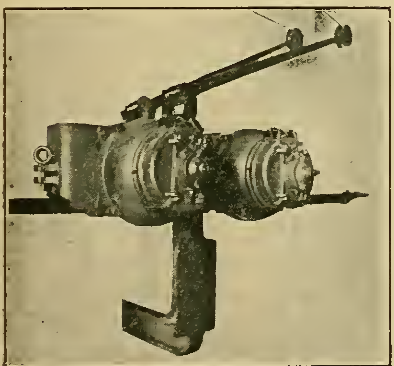


FIG. 10. FRONT VIEW. SIDE BEARING. DOUBLE TROLLEY.

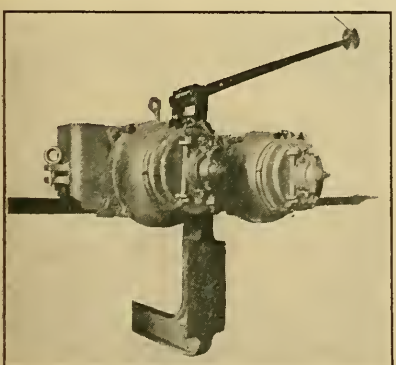


FIG. 11. SINGLE TROLLEY. SIDE BEARING.

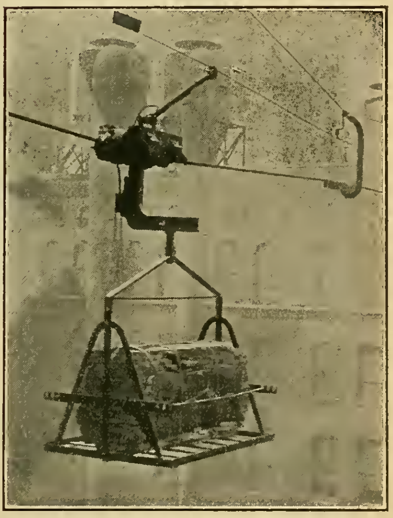


FIG. 12. Side bearing telpher in operation. Illustrating method of suspension, also the carrier, section insulator, hanger, suspension and track cables with trolley wire.

beneath the driving wheels. Sometimes two telphers are connected up together in a single truck, this giving what is called a double telpher; or a trailing wheel is used after a double telpher, in order to distribute the weight over a greater portion of the track. This is necessary when the weight of the load to be carried is great. Fig. 13 shows quite fully this weight distribution. In all telpherage work, gears are rarely used except for very heavy work or on steep grades. The frames of the later telphers are made in one casting, and the driving wheels are of steel, this having been determined to be the best material.

*Motors.* The motors are waterproof and dustproof and are compound wound for automatic work. When a telpherman goes with the telpher, the series winding is employed. There is also used a special series coil to give greater torque when starting. The telpher is placed above the track, thereby keep-

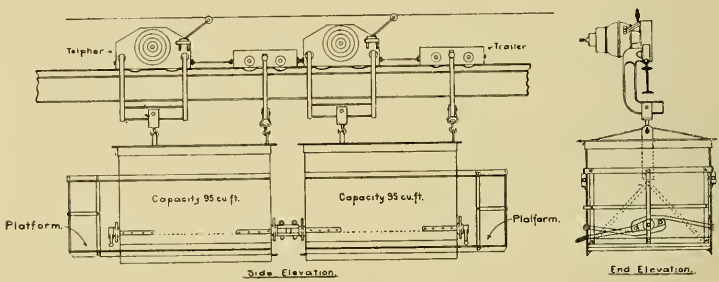



FIG. 13. The double telpher; maximum traction; capacity, four tons of coal, or 95 cubic feet; speed, 800 to 1,200 feet per minute. Side-dumping bucket operated by telpherman; controlled from either end. Telphers can be operated separately.

Three of these double telphers have a capacity of 250 tons of coal per hour over 2,000 feet of track. Labor, power and maintenance less than one cent per ton.

ing the motors from injury, while there is also no danger of their coming in contact with the carriers or being otherwise injured.

*Hoists.* The hoist is suspended below the telpher, or sometimes from a trailer drawn by the telpher. Special attention has been paid in the later designs of hoists to use as little head room as possible. It was deemed best at first to combine the telpher and hoist, but there were so many cases where it was necessary to use the telpher alone without the hoist, and also where it was advisable to put the hoist on the trailer instead of on the telpher, that experience has shown that it is better to make the telpher and hoist two separate pieces

of apparatus. Greater simplicity has also been obtained and a correspondingly lower maintenance reached. There are many other interesting details concerning hoists, as to the speed, lift and construction, which it is necessary to omit here.

*Brakes.* Two distinct types of brake are used on telphers, either hand brakes or solenoid brakes, both of which are arranged to apply pressure to the wheels or to grip the track. In regard to the solenoid brake, it is only necessary to explain that it works automatically, the solenoid being placed in series with the armature. A spring normally holds the brake on the

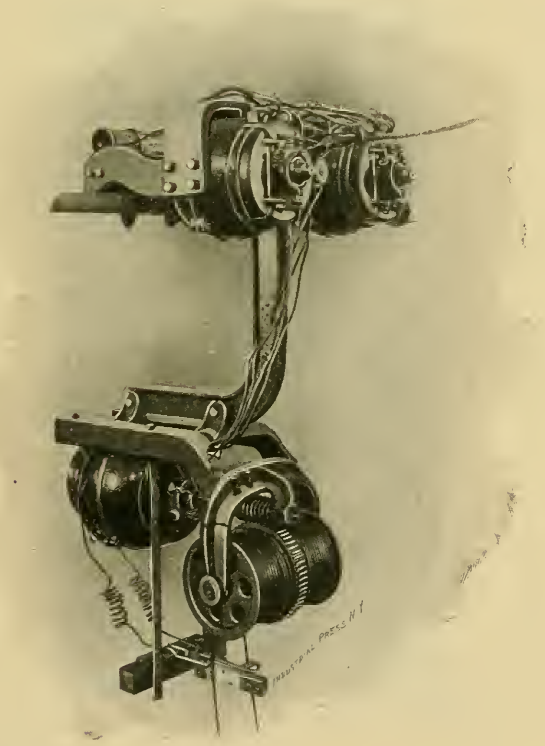


FIG. 14. ELECTRIC HOIST SUSPENDED FROM TELPHER.

wheel or the track. If, however, from any cause, the amount of current passing through the solenoid is reduced, whether by means of external resistance or by reason of the additional counter-electromotive force generated by the armature, due to running at a high speed, the solenoid becomes weakened and the brake is applied. An air cushion is arranged so that the brakes will be applied gradually.

*Trailers.* It is often advisable, where a large amount of material is to be carried, especially over one track, to use trailers. These consist generally of a two-wheeled truck, below which is suspended a bucket or other suitable form of carrier, or even the hoist, as the case may require. It is customary, where a large amount of material is to be carried, to arrange a long train carrying as much as ten tons. The order of procession is, first, a telpher with four or five trailers, then another telpher and four or five trailers, and a telpher at each

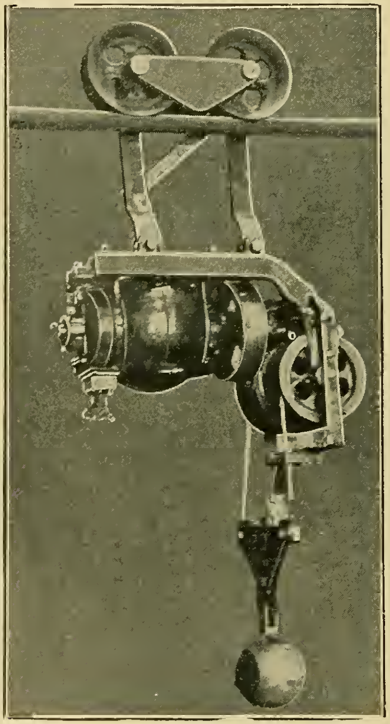


Fig. 15. Electric Hoist and Trailer.

end. The placing of these telphers at intervals greatly adds to the traction, while the distribution of weight over the whole span, or over two or three spans, enables much lighter construction to be used for greater capacity.

*Layouts.* Much engineering skill is required to lay out or plan the telpher lines for any proposed work in order to decide whether the line should be single or double, and the weight to be carried by each unit. The installations should be so

planned that the expense will be reduced to a minimum, and further, that the track will not interfere with existing machinery or buildings, taking care to avoid an excessive number of curves and switches, as these add more or less to the expense, particularly to the cost of erection. It is necessary therefore, for the selling engineer to be thoroughly trained in this part of the work, or else have the necessary engineering knowledge derived from some other similar business. It may readily be understood that it is impossible to give general prices for telpherage work. Complete specification blanks, with many necessary questions, are, therefore, provided, and the replies to these questions, together with a blue print showing a plan and elevation, are generally sufficient for the company to give a complete estimate for any proposed installation.

*Method of Operation.* It is difficult to treat in a general way of the method of operation. In automatic lines it is necessary to provide appliances whereby it is impossible for an unskilled operator to injure the telpher. In order, therefore, to provide for contingencies, a "dead section" is placed at each end of the line, the middle of the line being generally left alive. Upon closing a spring switch, the dead section is energized so long as the operator keeps his hand on the switch, which is usually only a few seconds, during which time the telpher passes to that portion of the line which is always alive. When it reaches the other end, it comes upon the dead section and then either slows down of its own accord, or else a mechanical or solenoid brake is applied. The telpher then passes under the reversing arrangement and it is therefore reversed, either with no current in the line or else with a high resistance. If the telpher is at the further end of the line, the operator at the near end, by closing a switch, can bring it back to him. The dead sections at the end of the line, which have current only so long as the hand is held upon the spring switch, render the line as safe as possible against the telpher coming in contact with the terminal posts. An automatic block system prevents collision of telphers.

*Curves.* The curves are solid rail and likewise the trolley track, where there is a curve, especially when it has a short radius. Wherever it is necessary to pass around a curve, to take turnouts or crossovers, a resistance is inserted in the trolley circuit, whereby the telpher automatically reduces its speed while it is traversing the curve or turnout or approaching a crossover switch. As soon as it reaches the other side of the

curve it receives full voltage and continues at its normal speed. In regular service the speed varies from 300 or 800 feet per minute, up to 20 miles per hour, or even more, when required. The slower speeds are used when the lines are short and where there are many curves, particularly for factory and foundry

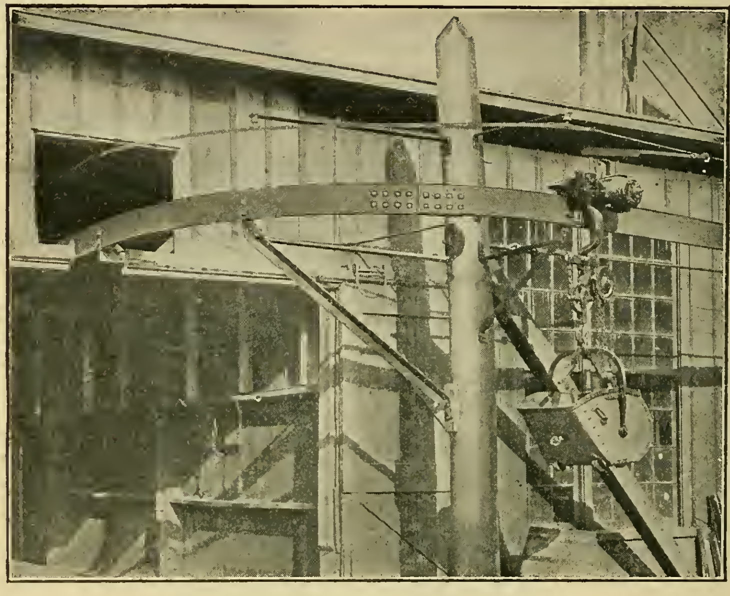


FIG. 16. TELPHER WITH AUTOMATIC DUMPING BUCKET TRAVERSING A CURVE. This shows a telpherage plant located at Buffalo, N. Y. This installation is interesting on account of its automatic features. The bucket is loaded at the cars and the load is transported by electricity to the end of the line, where the bucket automatically dumps its load. The telpher reverses itself and returns with the empty bucket to the cars for another load. The telpher may be operated by unskilled labor with the minimum of expense for power, maintenance and first cost. Power is less than one horse. The material which is dumped into a hopper is then elevated to the upper story. This line consists of a straight section and a right angle curve. A portion is cable, and the curve and the track in the building are solid rail. The line is supported, as will be observed from the photograph, from ordinary telegraph poles, and is an excellent example of simple construction.

work. For lines running across the country a speed in excess of 20 miles per hour can be obtained, but with the higher speeds the cost of the construction increases, certain special devices being necessary. Even for installations which are termed "cross country work," 15 to 20 miles per hour has been found amply sufficient.

As to what the ultimate capacity on grades may be, this has not been fully determined. Experimentally more than 20 per cent has been reached. In actual practice the greatest grade equipped has been 12 per cent., and thus far there seems to be ample traction.

THEORETICAL HORSE POWER NECESSARY TO PROPEL 1,000 POUNDS AT VARIOUS SPEEDS AND UP VARIOUS GRADES AT SAME SPEEDS.

| Grades in per cent. | SPEED IN MILES PER HOUR. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 20 | 25 |
| 0 | .027 | .053 | .080 | .107 | .133 | .160 | .187 | .213 | .240 | .267 | .320 | .400 | .533 | .667 |
| 1 | .053 | .107 | .160 | .213 | .267 | .320 | .373 | .427 | .480 | .533 | .640 | .800 | 1.07 | 1.33 |
| 2 | .080 | .160 | .240 | .320 | .400 | .480 | .560 | .640 | .720 | .800 | .960 | 1.20 | 1.60 | 2.00 |
| 3 | .106 | .213 | .320 | .427 | .533 | .640 | .747 | .853 | .960 | 1.07 | 1.28 | 1.60 | 2.13 | 2.67 |
| 4 | .133 | .267 | .400 | .533 | .667 | .800 | .933 | 1.07 | 1.20 | 1.33 | 1.60 | 2.00 | 2.67 | 3.33 |
| 5 | .160 | .320 | .480 | .640 | .800 | .960 | 1.12 | 1.28 | 1.44 | 1.60 | 1.92 | 2.40 | 3.20 | 4.00 |
| 6 | .186 | .373 | .560 | .747 | .933 | 1.12 | 1.30 | 1 49 | 1.68 | 1.87 | 2.24 | 2.80 | 3.73 | 4.67 |
| 7 | .215 | .427 | .640 | .853 | 1.07 | 1.28 | 1.49 | 1.71 | 1.92 | 2.14 | 2.56 | 3.20 | 4.27 | 5.33 |
| 8 | .241 | .480 | .720 | .960 | 1.20 | 1.44 | 2.68 | 1.92 | 2,16 | 2.40 | 2.88 | 3.60 | 4.80 | 6.00 |
| 9 | .267 | .533 | .800 | 1.07 | 1.33 | 1.60 | 1.87 | 2.13 | 2.40 | 2.67 | 3.20 | 4.00 | 5.33 | 6.67 |
| 10 | .293 | .586 | .880 | 1.17 | 1.47 | 1.76 | 2.05 | 2.34 | 2.64 | 3.03 | 3.52 | 4.40 | 5.36 | 7.33 |
| 11 | .320 | .640 | .960 | 1.28 | 1.60 | 1.92 | 2.24 | 2.55 | 2.88 | 3.20 | 3.84 | 4.80 | 6.40 | 8.00 |
| 12 | .346 | .693 | 1.040 | 1.38 | 1.73 | 2.08 | 2.43 | 2.77 | 3.12 | 3.46 | 4.16 | 5.20 | 6.93 | 8.67 |

Although the amount of power may be easily figured out, it is somewhat in the nature of a surprise when we consider that to carry half a ton on a level track at a speed of six miles per hour, much less than a horse power is required, including all losses. This is a revelation to most manufacturers. The absence of gearing, the motors being attached directly to the driving wheels, gives the highest efficiency possible, as well as freedom from noise.

The actual power consumed, according to the table given above, at six miles per hour for 1,000 pounds on a level is only .16 h. p. It is, therefore, seen that ample allowance is made for losses and extra weights not provided for in the load, such as down-comes, buckets or carriers. The power required increases greatly with the grades and when this reaches certain limits it is deemed advisable to use gears in order to reduce weight of motors.

*Maintenance.* Although telpherage has not as yet been in operation for a sufficient number of years to determine exactly what the maintenance will be, yet, at the same time, in lines that have been operated for a year and a half, the maintenance has been exceedingly small. As stated above, the driving wheels being of steel, none of them has thus far shown any signs of wear, and trailer wheels are of the same material and type

as those which have been used on mechanical cable lines for ten years and are still in good serviceable condition. The motors, on account of their elevated position, have shown a better maintenance than stationary motors of the same type. This may possibly result from the extra care taken in their construction. In regard to the track, this has also shown most excellent results, also due to the fact that it is above grit and dirt and crossing teams and, when well painted, has shown little signs of wear or depreciation. Wherever a change is made from cable to solid rail, or where cable passes over hangers or brackets, it is pro-

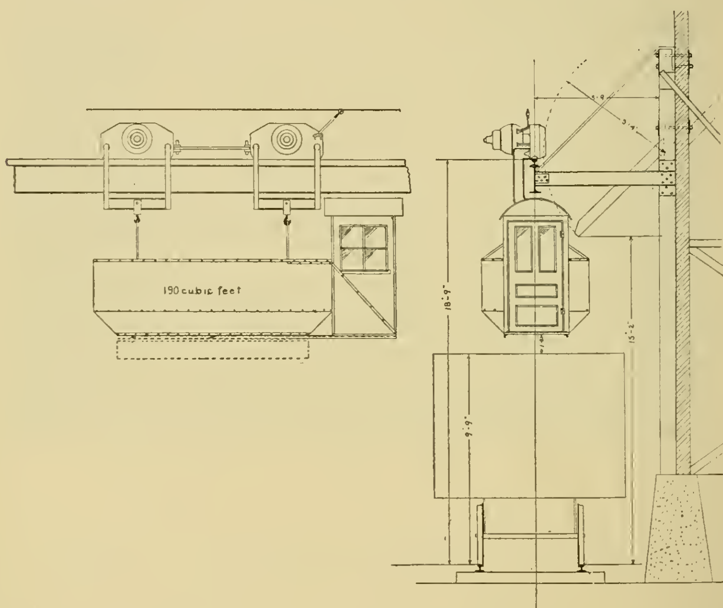



FIG. 17. Plan and elevation of another form of double telpher with four-ton coal bucket, bottom dumping, cab for telpherman. The side elevation shows method of attachment to side of building and loading chute.

tected by what are called "shields," these being arranged so that they may be readily replaced. The cable is also protected at the hanger and brackets by steel shields.

*Capacity.* An important feature in telpherage is the capacity of the line. In general, I can say that there is no other form of conveyor known which shows such flexibility. This is due to the use of electricity, and the features which apply to the street railway, apply also to telpherage. There are two factors of special importance in relation to the capacity of the line:

first, the speed, and second, the number of telphers and trailers. The line may be laid out with one telpher and a few trailers. More telphers or trailers may be added, and, if upon a single line, coupled in long trains. If it is desired still further to in-increase the capacity, the line may be made double, while if de-

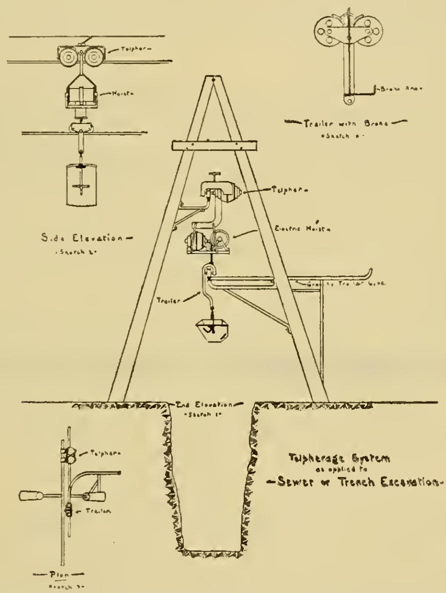



FIG. 18. In sewer or trench excavation the method of operation it as follows: The bucket has attached to it a trailer wheel. The buckets and wheel are lowered into the excavation, and the bucket, when filled, is raised by the electric hoist so that the wheel of the trailer engages the gravity rail. The load then passes by gravity to the place desired and is automatically dumped. This may be along the line of excavation, for refilling the trench, or to the right or left, for unloading into carts, or in connection with the telpher to any desired distance. The telpher has the flexibility of a trolley car. This method is a combination of telpher and gravity lines, and the amount of work that can be accomplished by it with the minimum of labor is remarkable.

sired, the carriers may also be made continuous so as to take boxes and barrels or other freight as fast as they can be delivered to the carriers of the telphers and trailers.

The flexibility of telpherage in regard to capacity is wonderful, and is a most important feature. In fact, it may be said that there is practically no limit to flexibility. In one plant, about to be installed, the proposed capacity is 250 tons per

hour, over a distance of one-half a mile, the material to be distributed over an area of about an acre. Any one who is familiar with conveying will note that there is no other system that can do this so economically, and in a way so thoroughly satisfactory as telpherage.

The nature of installation varies with the amount of material to be carried, so that if the amount to be carried is small, the expenditure need not be great. Figs. 17, 18 and 19 show various applications.

*Applications of Telpherage* There are few factories where the installation of an overhead telpherage system would not prove a valuable investment. The question is often asked: Is telpherage suited for carrying specific articles? And the reply may

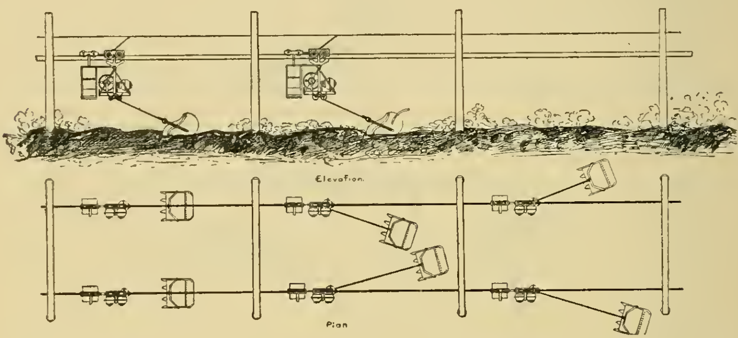



FIG. 19. Excavating and leveling in preparing roadbeds for railroads. The function of the telpher is to transport the hoist, bucket and load The hoist does the excavating and elevating. The hoist automatically brakes itself either upon the girder rail or grips the cable as soon as there is any longitudinal strain. Used also for scooping and transporting earth, sand, ashes or coal.

be made that it is adapted to the conveying of the products of almost every kind of manufacturing.

In these days of consolidation of companies, factories cover immense areas. The individual buildings are frequently large enough in themselves to utilize a telpher line. In many cases, on account of fire risks or of convenience in manufacturing, the buildings are widely separated from each other, and yet constant communication is necessary. Overhead telpherage, therefore, in manufacturing establishments is used for carrying the raw material, implements and finished products from one part of the grounds to another, from one building to another, or, even from one part of a building to another part, moving raw material from

cars or vessels to the works and then taking the finished products to the railway station, or the wharf, for shipment; and for conveying refuse away from the factory. In this connection we might mention the conveying of ashes or slag to the dump heap.

Telpherage may also be extensively used for handling coal. It serves to reduce greatly the cost of transportation on plantations and farms and may be economicallyused for handling coffee, sugar cane, tobacco, fruits and hay and other like products.

In general, it may be said, that wherever material is to be carried to a distance, there is no power so flexible, so economical in first cost of installation, costing so little for power or the expense of maintenance, and with such great capacity as telpherage. It may, therefore, be designated a material transportation by an immaterial fluid, and may well be called one of the most important of the many adaptations of electricity.

If time, floor space, or labor is being consumed in the conveying of any kind of material in any plant, plantation or mine, each can be saved by the installation of telpherage. Any condition at any manufacturing establishment which presents a requirement for hauling by man or team, whether in transmission of product during the various stages of manufacture, the movement of materials by which the product is to be treated or the handling of fuel, and ashes or other waste, is a logical opening for the installation of telpherage.

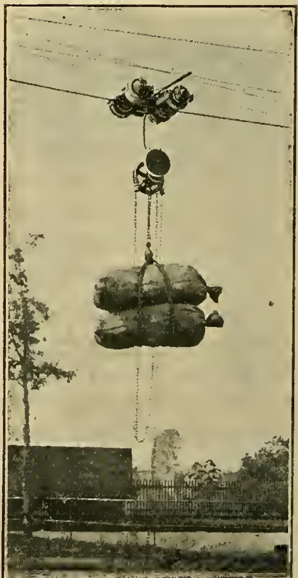
When you install telpherage you employ a machine to do the work of men. Machinery is the most powerful factor for economy in production. Telpherage is almost human in its operation, works any number of hours per day and never tires. In many cases you start the telpher, it conveys, automatically leaves its load at the destination and returns for another load. Telpherage conveys 50 lbs. or 50,000 lbs. solids or liquids.

Much more can be said about telpherage, but the above will give a general idea of its work. Many plants have been installed and many more are being installed daily, and in many instances duplicate orders are being received from former customers.

COAL AND ASHES.

AUTOMATIC SELF-DUMPING.

SUGAR.



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# THE PRESENT STATUS OF THE SEWAGE PROBLEM IN ENGLAND.

By Prof. Leonard P. Kinnicutt, Worcester Polytechnic Institute, Member Boston Society of Civil Engineers.

[Read before the Society, March 19, 1902.*]

Two years ago I had the pleasure of describing to you some experiments that had been made in England on the bacterial treatment of sewage and the results that had been obtained up to that time. To-night I have been asked to speak to you about the work of the past two years, and to give my opinion in what way, if any, this work has modified or changed the views that were held two years ago on bacterial treatment of sewage. I have, therefore, taken as the subject, "The present status of the sewage problem in England."

The subject divides itself naturally into three heads—"Septic Tanks," "Contact Beds," "Intermittent Continuous Filtration Methods."

## THE SEPTIC TANK.

During the past two years the septic tank has grown in favor and has been installed in a great many places in England, and the general opinion is that it certainly has its place in the bacterial purification of sewage. What does it do?

It equalizes the composition of the sewage.

It removes from the sewage not only suspended matter, but a portion of the solids that are in solution.

It changes the character of the sewage, increasing, as a rule, the amount of free ammonia, and decreasing the albuminoid ammonia.

It prevents, to a large degree, the clogging of bacterial beds.

It liquefies, or changes into gaseous products, a portion of the suspended matter at the bottom of the tank, thus reducing the amount of sludge.

It renders, as a rule, the sewage more easily acted upon by nitrifying bacteria.

As to the exact amount of work that the septic tank does in each of the above-named ways, opinions differ. It depends, in my opinion, on the character of the sewage. As general statements, the following, I think, may be accepted:

*Manuscript received March 26, 1902.—Secretary, Ass'n of Eng. Socs.

That the amount of total solid matter removed equals about 26 per cent. of the total solid matter in the sewage.

That the amount of suspended solids and solids in solution removed depends greatly on the character of the sewage. With an alkaline domestic sewage the amount of suspended matter removed is greater and the amount of solid matter in solution less than with a sewage containing free acid and iron salts.

The following analyses give us an idea of the action of the septic tank on the solid matter in sewage. They are all means of a large number of analyses, that of Worcester being the average of weekly samples taken during fifteen months:

Solids in Sewage and Septic Tank Effluent.

Parts per 100,000.

| | Total Solids. | | | Soluble Solids. | | | Suspended Solids. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sewage. | Effluent. | Per cent. Removed. | Sewage. | Effluent. | Per cent. Removed. | Sewage. | Effluent. | Per cent. Removed. |
| Exeter . . . . | 77.70 | 59.20 | 23.81 | 42.70 | 43.80 | 2.57 | 35.00 | 15.40 | 56.01 |
| Leeds . . . . | 123.10 | 80.50 | 34.61 | 75.50 | 66.40 | 12.05 | 47.60 | 14.10 | 70.37 |
| Manchester . . | 131.43 | 95.66 | 27.22 | 94.28 | 79.71 | 15.45 | 37.15 | 15.95 | 57.06 |
| Worcester . . | 74.60 | 58.00 | 22.25 | 50.54 | 40.09 | 20.67 | 20.06 | 17.90 | 25.57 |

The amount of total organic matter removed, as judged from the albuminoid ammonia, also depends upon the character of the sewage. It ranges from 17½ per cent., obtained by Dibden, at Exeter, to 60 per cent., obtained by Clark, with a small experimental tank in his experiments at Lawrence in 1900. Rideal gives 46 per cent. as the average amount of albuminoid ammonia removed. In Worcester, using an experimental closed tank holding 2250 gallons, I found it to be 26 per cent. As a rule, the stronger the sewage the greater will be the percentage of organic matter removed; more is removed in warm weather than in cold weather, and more from an alkaline domestic sewage than from an acid sewage containing manufacturing waste.

The amount of sludge decomposed, I think, has been generally overestimated. My opinion is that it does not usually exceed 30 per cent. of the total suspended matter arrested in the tank.

Whether or not the septic tank renders the sewage more easily acted upon by nitrifying bacteria has been disputed. It seems to me, as a rule, it does, and the exceptions are caused by too long contact of the sewage with anaerobic bacteria.

The rate of flow through the tank should depend on the character of the sewage and the changes it has undergone before it enters the tank. Twelve to twenty-four hours as the time of flow through the tank is the one usually accepted. There is as yet no way of determining the best rate of flow for a given sewage. From experiments I have made during the past year on the gases given off from the septic tank, I think that the analysis of the gas may give us a clew as to the time the sewage should remain in the tank.

The amount of gas given off from a septic tank has not as yet been definitely determined. I am inclined to agree with Mr. Fowler that in periods of full activity the amount is about one cubic foot per hundred gallons of sewage. In winter, however, the amount given off is much smaller than in summer.

The gas evolved is a mixture of methane, nitrogen and carbon dioxide, containing little, if any, hydrogen.

As to the odor from a septic tank, some say it is very offensive, others that it is hardly noticeable. Both are right. In England I have seen many tanks which gave off most offensive odors and others which gave very little odor. Why this is so we do not know, nor can it be told beforehand whether a certain sewage will or will not give off offensive odors while septic action is taking place. At the present time I believe if tanks are to be erected near dwelling houses or frequently-traveled roads the only safe rule is to build closed tanks.

Another very interesting point, though possibly not of practical importance, is the formation of a crust on the surface of the liquid in the septic tanks. Formerly it was considered that if a crust did not form, no true septic action was taking place. As a rule a crust does begin to form four to six weeks after a septic tank has been started, which increases in thickness and is permanent. Yet there are a number of cases known where a crust has never formed, and others where, after it has formed, it has again disappeared, and in others where, after disappearing, it has again formed. Fig. 1 gives a good idea of the crust that usually forms over the liquid in a septic tank, and Fig. 2 shows what was constantly taking place at Worcester, in the summer of 1900,—the eruption of a large volume of gas through the crust.

Both at Leeds and Manchester there are tanks covered with a thick crust and tanks practically free from crust. At present

there is no explanation of these facts, and we say the formation of a crust is only an incident to the process.

### CONTACT BEDS.

There is no question that there is to-day a greater diversity of opinion in England regarding contact beds than there was two years ago. It is generally conceded that with a few exceptions all kinds of sewage, after having undergone preliminary treatment by the septic tank process, can be purified by contact beds so as not to undergo secondary putrefaction; that the amount that can thus be purified is about 350,000 gallons per day per acre, and that in some cases the amount may run as high as 500,000 gallons per day. A small but very perfect double contact bed plant is shown in Fig. 3.

The diversity of opinion is not as regards the purification of clarified sewage, but on the question, how long will contact beds treating clarified or septic-tank sewage at the above rate retain their efficiency?

The permanent efficiency of a contact bed depends upon the non-filling up of the void spaces between the surfaces of the filling material, and as the liquid capacity depends on the cubic area of these void spaces, the efficiency of a bed will remain practically constant if the liquid capacity can be maintained.

The chief causes of loss in capacity of contact beds are settling down of material, breaking down of material, insoluble matter entering the bed and growth of organisms.

Everyone agrees that there is a loss of capacity in contact beds by the settling down of the filling material; this, however, takes place in the first few months of use; it amounts to about one-third of the initial liquid capacity and can be taken into account when making the beds.

Breaking down of the filling material undoubtedly causes a loss, but if a sufficiently hard filling material is used this loss is comparatively small.

The loss of liquid capacity from these two causes is, therefore, not of a serious character, being of a known amount or not increasing after the first few months. The loss that takes place during the working of the bed is caused by insoluble matter entering the bed and by the growth of organisms. If this loss cannot be prevented or controlled, it is a most serious matter, for upon the prevention or control depends the economical working of the contact process. The solid matter that is carried on to a bed depends upon the character of the sewage and the effectiveness of previous

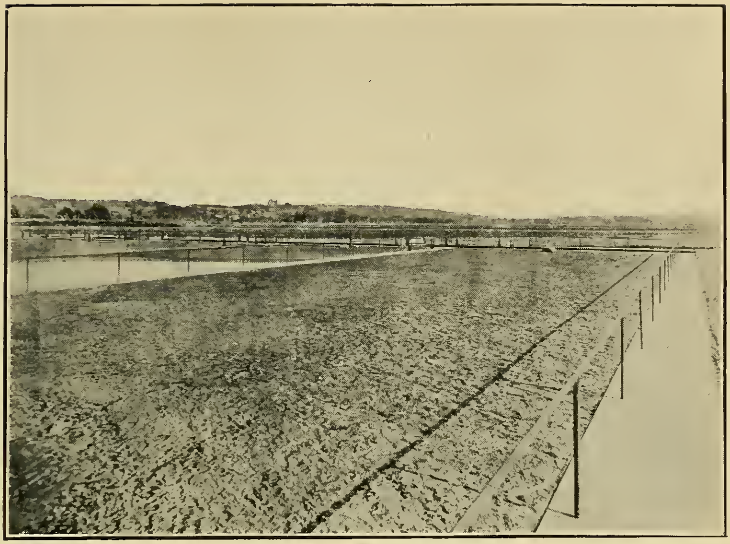

Fig. 1. Open Septic Tank, showing Crust, Worcester, Mass., 1900.

Fig. 2. Open Septic Tank, showing Crust and an Eruption of Gas through Crust, Worcester, Mass., 1900.

treatment. Without question, the greater part of the suspended matter must be removed, as can be done by chemical precipitation or the septic tank, before the sewage is run upon the beds. If this is done the remaining suspended matter will consist chiefly of sand and clay in a fine state of subdivision, and with acid iron sewage a part of the suspended matter will be iron sulphide. It appears, from experiments made in England, as though these substances could be retained in the top three inches of the bed if the upper inches of the filling material are of much finer character than the rest of the bed. These upper three inches, when it becomes necessary, can be removed and replaced without any very great expense.

The chief and serious question, and the one about which opinions most differ, is the loss of capacity of a bed by the growth of organisms through the whole bed and the deposition in the bed of the ash or non-putrescible part of organic substances. As to the growth of organisms, it has been shown that if the material of a contact bed in active condition be examined every piece is seen to be coated over with a slimy growth, which, if removed and dried, cuts like a jelly. Under the microscope the slime is found to be chiefly composed of bacteria and zooloca. It is on the presence of this slimy material that the action of the bed depends; the greater the amount, up to a certain limit, the greater the efficiency; if, however, this limit is overreached, the liquid capacity is greatly diminished, the bed becomes spongy and the water will not drain away.

Can this growth of organisms be regulated so that the bed will do its proper work and at the same time not lose its liquid capacity? Further, is serious trouble to be apprehended from the deposition of the non-putrescible part of organic substances?

Mr. Fowler believes the growth of organisms can be regulated, and that no serious trouble will be caused by the ash of organic substances. His belief seems to be borne out by the experiments made in 1900 to 1901 at Manchester.*

Three experimental contact beds, each of 1-76 of an acre, effective superficial area, received from March, 1900, to March, 1901, septic-tank sewage at rates corresponding to 377,390, 395,290 and 592,810 gallons per day per acre. The liquid capacity of these beds was frequently determined, and as a result, no permanent loss of capacity was found to have taken place. In this connection it may be well to call to your attention a very valuable paper by Mr.

*City of Manchester. River Department. Annual Report. Year ending March 27, 1901, page 61.

Fowler on "Some Points in the Management of the Septic Tank and Bacterial Contact Beds," published by Bailliere, Tindall & Cox, London, 1901.

Mr. Harrison,* on the other hand, from his work at Leeds takes the opposite view. He believes that the loss of liquid capacity, depending both on the retention of the ash of organic substances, similar to the humus of the soil, and to the growth of organisms, cannot be permanently prevented, no matter how carefully the beds are worked. He regards the loss of liquid capacity, or, as he calls it, "sludging up of the beds," as so serious a matter, necessitating as it does the periodical renewal of the filling material, that, in his opinion, the application of the contact method by any town possessing a sewage approximating to that of Leeds, *i.e.*, sewage containing manufacturing waste, with large amounts of free acid and iron salts, as seemingly impossible.

Mr. K. T. Campbell,† Borough Engineer of Huddersfield, as the result of three years' experiments at Huddersfield, takes rather an intermediate position. He believes the process is impracticable if crude sewage is run upon the beds, and that with septic or chemically-treated sewage contact beds will not retain indefinitely their capacity, and that after a certain number of years the capacity will be reduced to such an extent as to render necessary the washing or riddling of the whole filling material.

The results of the very interesting experiments of Professor Dunbar and Dr. Thum, made during the past three years at Hamburg and just published by Aldenbourg, of Munich, agree with the general opinion that with raw sewage the liquid capacity of contact beds can not be maintained, but differ in that they appear to show that it makes no difference whether raw sewage or septic sewage is run upon the beds. This last very surprising result is very likely due to the fact that the 7000 gallons required to fill the bed,—representing about one-third of the total contents of the septic tank used,—were drawn off from the tank in a few minutes, while the rate should have been, and would have been in actual practice, not over 1200 gallons per hour. A large amount of suspended matter must thus have been brought upon the beds, which would not have occurred if the septic tank had been run in the usual way.

The results that I have quoted, and more could be given, show the reason of the differences in opinion that to-day prevail in England regarding the contact method, and though personally, from what I saw in England last year, I am still of the opinion that if

*Journal Soc. Chem. Industry*, 1901, p. 516.

†*Surveyor*, September 6, 1901. Supplement.

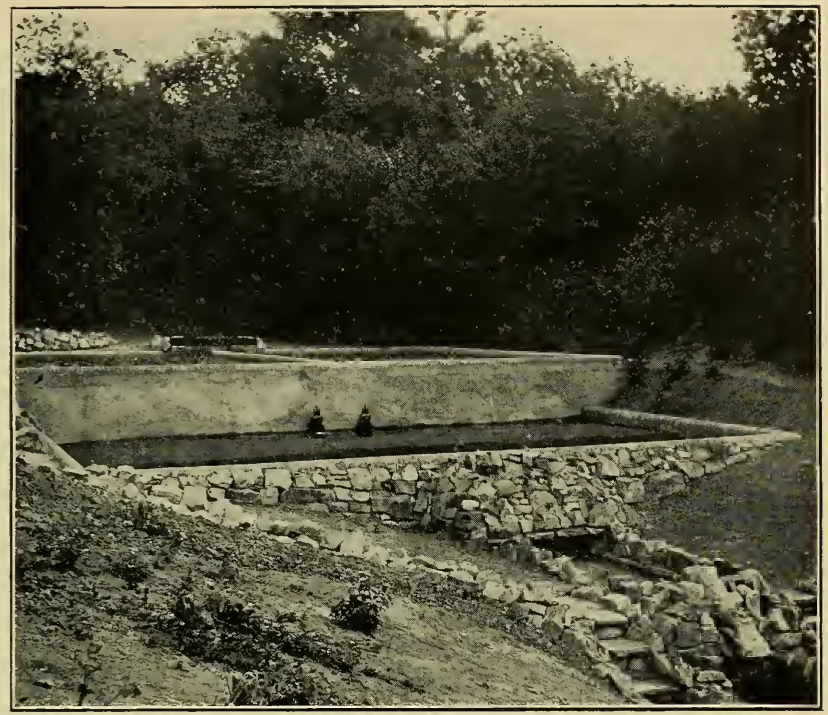

FIG. 3. DIBDEN'S DOUBLE CONTACT BEDS. PRIVATE ESTATE IN ENGLAND, 1899.

FIG. 4. CONTACT BEDS, MANCHESTER, ENGLAND, SHOWING CONSTRUCTION, 1901.

properly worked the contact method will prove a successful way of treating clarified sewage, there is no question but that it is a method which requires skilful management, and one that can only give the best results when under the direct oversight and care of a trained engineer or chemist.

My opinion that contact beds, when properly managed, do give good results and that the liquid capacity of the beds can be well maintained is no doubt influenced by the work that has been and is being done at Oldham, England.

Oldham is a city of 150,000 inhabitants, in Lancashire, only a few miles from Manchester, and sewered on the combined system. Originally the sewage was treated chemically, but in 1897 it was decided to substitute for this method contact beds, and at the present time, October, 1901, two million gallons are being treated on 4½ acres of contact beds.

The sewage, as it comes to the plant, passes through a detritus tank, which is fitted with a revolving dredger and two sets of screens and rakes. These tanks arrest a considerable quantity of rags, sticks, etc., as well as a large quantity of mineral matter, road washings, sand and ashes.

From these tanks it flows into twelve settling tanks, each 128 x 36 x 6 feet 1½ inches and holding 176,400 gallons, and then into the effluent channel, and of this effluent about two million gallons each day are carried to the contact beds.

The beds are seventeen in number, average size about 150 x 90 feet, depth from 1 foot 9 inches to 3 feet. Their construction is very simple. They are lined around their sides with planks 9 x 3 inches; the bottoms are not concreted, as the soil is clay, and water-tight. Each bed is underdrained by two rows of 12-inch land tiles laid joint to joint, and over the tiles are placed large clinkers about the size of a man's fist. The main filling material is hard cinder, everything under ¼-inch being sifted out.

The cost of the beds is remarkably low, averaging about $3500 per acre. These beds do not receive septic, but only clarified sewage from sedimentation tanks; yet, as to the permanency of their liquid capacity, Mr. A. S. Wylie, Manager and Chemist of the Oldham works, a most competent man, says:* "That the four bacterial contact beds which have been constantly at work since 1897 show no serious sign of clogging, and the effluent conforms to the Mersey and Irwell Standard." He is of the opinion that these beds will last for years.

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*Private communication.

In 1900, experiments were begun at Oldham with septic sewage. One of the sedimentation tanks was allowed to become septic; a scum was formed, increasing until it measured 8 inches in thickness. The effluent was run upon two first contact beds, and then for a secondary contact on two lower beds.

It took some little time for the beds which had been receiving sewage from the subsidence tanks to become accustomed to septic sewage, but the effluent continued to improve till the filtrate, even from the first contact beds, always stood the incubator test, and would be emptied into a stream not used as a water supply.

Mr. Wylie states, as the result of these experiments, "That with a proper arrangement of grit and screening chambers, septic tanks and storm water beds I would be willing to guarantee a non-putrefactive filtrate at the rate of 500,000 gallons per acre per day from first contact beds, and at the rate of 1,000,000 gallons, at least, from second contact beds."

The experiments of Mr. Fowler which I have quoted have led to one very interesting and important result,—the adoption of the contact bed method for the treatment of Manchester sewage. Not only have plans and estimates been made and accepted for the laying out of sixty one-half acre contact beds and a storm filter area, but the work of constructing these beds is now in progress. Four are already finished and working and eight more are nearing completion.

The beds are of about one-half acre area and of an average depth of three feet five inches. The walls of the beds and of the distributing carriers are made of concrete 18 inches thick. The inlet reservoirs, distributing weirs and outlet walls are also of concrete.

The bottom of the beds is of concrete, 6 inches thick, and the under drains sunk in the concrete and covered with perforated tiles are 12 inches wide and 10 inches deep, with a fall of one in four hundred. They radiate from the center of one side of the bed, and at the further end of the bed are 18 feet apart. The distributing weirs are directly over the outlet channels. (Fig. 4.)

The main filling material is hard, coarse cinder which has been rejected by a ¼-inch screen, the upper three inches being of screenings which pass this mesh. (Fig. 5.)

The filling of the bed with tank effluent and opening the outlet channels so as to empty the bed is controlled by an electrical device. so that both operations can be done directly from the engine room by pressing a button.

The cost of these beds is estimated at £3500, or about $17,500 an acre.

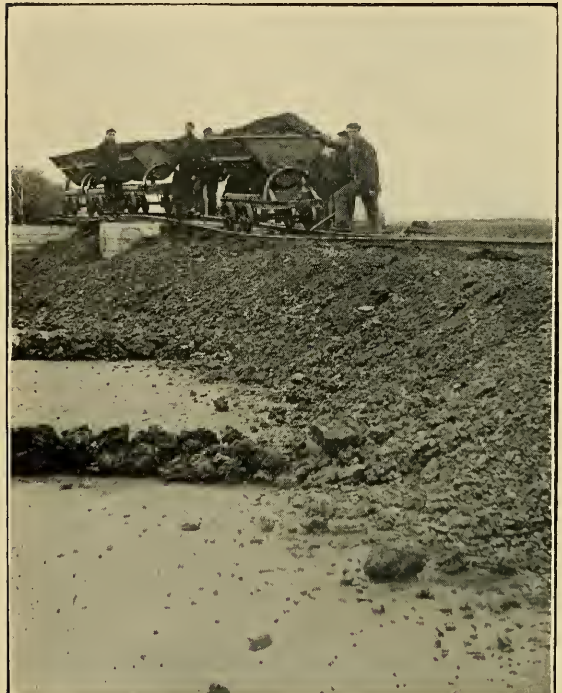

Fig. 5. Contact Beds, Manchester, England, 1901, showing Filling Material. Largest Pieces placed over the Drains.

Fig. 6. The Whittaker & Bryant Filter, showing Construction, Church, near Accrington, England, 1900.

INTERMITTENT CONTINUOUS FILTRATION.

With the diversity of opinion regarding the practical success of the contact method of treatment of sewage there has arisen in England an expression of opinion in favor of the so-called Intermittent Continuous Filtration processes.

There is little doubt but the final purification of sewage is due to an oxidizing action brought about by bacteria, which require oxygen for their existence; and the main feature of all the methods for the final purification is to furnish sufficient oxygen to cause the greatest amount possible of bacterial action.

The advocates of continuous intermittent filtration methods claim that contact beds and the American intermittent filtration beds do not fulfill this requirement. They say that before the sewage is applied to the bed, the bed having been draining for some hours, does contain a large amount of air, and that it is at that time, and at that time only, that the bacteria are doing the maximum amount of work, *i.e.,* changing the nitrogen of the organic matter in the sewage that still moistens the filtering material into nitric nitrogen. When the sewage is applied the air is expelled, and during the time the bed remains full the bacteria cannot obtain a supply of oxygen, and their work is reduced to a minimum; that at this time no nitrogen is changed into nitric nitrogen, and that the nitric nitrogen that appears in the effluent is only the nitrogen that was changed to nitric nitrogen when the bed was empty. Further, that the bacteria being cut off entirely from air during two or three hours, become enfeebled and only partially recover their activity during the time the bed is empty.

There is more or less truth in these statements, and certainly at the present time in England the one question you are sure to be asked is, "What is your opinion on Continuous Intermittent Filtration?"

My answer was the same that I will give you to-night. I am very much interested in the work that is being done and believe that it should receive serious study and consideration. I also believe a greater amount of sewage can be treated by continuous filtration than by intermittent filtration or contact beds; yet I am still to be convinced that any of the methods I have seen are of wide applicability or could be used to advantage except where the question of area was one of greatest importance.

Such being my general opinion, I am to-night only going to describe to you, illustrating with slides, the various processes of continuous filtration that I have seen, in order to show you the work that is now being done in England on this method, making

very few comments on any of these processes, as a full discussion of this question would require at least a whole evening.

The first experiments on continuous filtration were those of Lowcock in 1892 and the late Colonel Waring in 1894. In the Lowcock experiments the attempt was made to purify crude sewage by forcing air into the gravel or broken stone filter. The result was the clogging of the filter. The reason of this, though not then known, is now understood, for to liquify the solid substances in sewage, especially the nitrogenous compounds, anaerobic action is necessary, and by forcing air into crude sewage, anaerobic action is prevented. For a similar reason, *i.e.* that the action is mainly aerobic, is the cause why serious trouble has been experienced when crude sewage has been applied to contact beds, and that less trouble has been experienced with intermittent filtration beds is due mainly to the greater comparative area of these beds. In the Waring experiments the suspended matter was first removed and only clarified sewage was applied, air being forced up through the filter. Waring plants have been built at Wellum Grove Park, Pa.; at Homewood, a suburb of Brooklyn, N. Y.; at East Cleveland, Ohio, and at several other places.

(*a*) Report of James Mansergh to the Sewage Commission of the city of Baltimore. Second report of the Commission, pages 83 to 85.

(*b*) "Purification of Sewage by Forced Aeration." George W. Waring, Jr. Printed by T. W. Marshall, Newport, R. I.

The plant at East Cleveland is the largest of these, and was constructed in 1899 by the City Waste Disposal Company of New York. It consists of six roughing filters, or strainers, area 3630 square feet, and one aerated filter bed, area 6248 square feet, divided into four compartments.

The amount of sewage treated is 150,000 gallons per day.

Mr. Frank S. Crobaugh, chemist for the Mayor and Council of East Cleveland, reported the average purification in the months of August, September, October and November as 93.71 per cent., calculated from the loss of albuminoid ammonia, and the bacterial purification as 92.97 per cent.

The continuous filters that are at the present time receiving serious attention in England do not attempt to treat crude sewage, but sewage that has been acted upon by the anaerobic bacteria, or from which all solid matter has been removed by chemicals, nor do they depend for aeration on forcing air into the filter, but on openness of construction and applying the partially purified sewage in thin streams or in the form of rain. Such filters are the Scott-

Moncrieff, the Ducat, the Whittaker & Bryant, the Stoddard and what may be called the Salford filter.

The Scott-Moncrieff filter differs from all the others in that it consists of a number of filters placed one above the other and separated from each other by air spaces of two to three inches. The filling material in each filter consists of 6 inches of broken coke of about 1-inch diameter. The septic-tank effluent is distributed by tipping troughs or by an automatic sprinkler on the surface of the material in the top filter and passes in thin streams through the spaces between the filters. The under filters are thus kept full of oxygen by the air carried down with the sewage.

The first experimental plant was erected at Ashstead. It consisted of nine trays, each tray having an effective area of only about 1 square foot and containing 7 inches of broken coke. The sewage was first passed upwards through a small tank containing broken stones, which acted as a septic tank, and then by means of tipping troughs was run upon the top filter in a fine stream.

A plant on this principle for treating 16,000 gallons per day was erected at Caterham Barracks in 1898. The septic tank was 42 x 20 feet and the filters were about the same size, so that the whole installation occupied only about 200 square yards. The purification is said to be very successful at Caterham, the final effluent, according to Dr. Rideal, when the filter is running at the rate of 350,000 gallons per acre, containing nine parts of nitrogen as nitric nitrogen.

In South Africa, the Scott-Moncrieff plants have been erected in several places and are stated as having been very successful. It is possible that in countries where the action of the bacteria would not be interfered with by cold weather this method might be used with success. The clogging of the filling material would take place chiefly in the top filter, and this material could be removed from time to time without great expense.

The Ducat filters differ very greatly in construction from the Scott-Moncrieff filters. These filters are designed to be always of the same size,—126 feet long by 36 feet wide,—equalling 504 square yards, and to deal with a flow of 100,000 gallons per day, equal to about 1,000,000 gallons per acre. The construction is such as to allow of the freest possible contact of air to all parts of the filter. The walls are built of open drain pipes 12 inches long and 4 inches in diameter, inclining inward, and supported by brick or iron piers 8 feet apart. The space enclosed is filled somewhat as follows:

There are placed on the cement floor lines of butt-jointed drain pipes, not closed at the ends, the space between the pipes and to the height of 6 inches above being filled with clean furnace clinker. Above this are placed 18 inches of clinker which have passed a ¼-inch mesh. On this is a layer of 3-inch drain pipes, connecting with the butt ends of the pipes of the wall of the filter. In a normal filter there are four of these sections, making the height of the filter 8 feet.

The sewage carrier is built on one of the long walls of the filter, and at every eighteen inches there are outlet pipes discharging into tipping troughs 36 feet long, 2 inches deep, placed 6 inches above the filter. Each one is supposed to deliver sewage at intervals of about 6 minutes.

The whole filter is surrounded with a brick wall and covered with a thatched roof. There are numerous doors and air inlet pipes on the sides of the wall, and twenty-eight ventilators in the roof for the escape of air.

The very free exposure to air causes a great cooling of the sewage in cold weather, and the filter is heated by steam passed through pipes at the bottom of the filter and between the brick walls and the filter.

A Ducat filter was put in operation at Hendin, England, in 1898, but the one I studied was an experimental one erected at Leeds under the direction of Colonel Ducat. The construction was similar to the description I have given. Crude sewage was raised to the top of the filter by a Tongye pump, and after having passed through a small grit chamber and a ⅜-inch screen, was distributed on the filter by tipping troughs at the rate of 200 gallons per square yard.

At first the filter was not run as a continuous filter, but was either worked continuously for 10 hours and allowed to rest for 14, or worked alternately for 10 hours and then rested for 14. Later, however, it was worked continuously.

The results obtained at Leeds were not satisfactory, owing possibly to the filling material being too fine. There was a tendency for the filter to clog and for the surface to become coated by the suspended matter in the sewage. This prevented sufficient aeration and the effluents were often poor. The best results obtained showed a purification of about 90 per cent.

The cost of construction of this filter is large, and being obliged to heat the filter adds very materially to the cost of maintenance. It does not seem, even if all that has been claimed for the process was true, that this form of filter could be of general application.

The Whittaker & Bryant filter is a circular or polygonal chamber about 61 feet in diameter and 9 feet high, containing a central air shaft. The bottom is made of cement with a collecting drain running along one diameter, connecting with which are tile drains set herring-bone-wise. The pigeon-hole walls of the chamber and air shaft are supported on short brick columns so that there is an air space between the walls and the concrete floor. The filling material between the outside walls and the air-shaft consists of coke 1½ inches or over in diameter. (Fig. 6.)

The sewage is distributed on the surface by an automatic sprinkler, into the delivery pipe of which is placed a steam pipe so that a small jet of steam can be blown into the sewage just before it is distributed on the filter. This raises the temperature of the sewage to about 70 degrees, which, in passing through the filter, raises the whole body of the filter to the same temperature. The heat, according to Mr. Whittaker, "not only keeps the bacteria at their fullest activity, but raises the temperature of the air in the interstices of the filter, thereby causing it to rise through the filter and fresh air to enter, rendering the filter self-ventilating and self-aerating."

The largest Whittaker-Bryant plant is at Church, near Accrington (Fig. 7), and at this place there are ten filters, each 20 yards diameter equaling 314.16 square yards area, and four of 15 yards diameter equaling 146.7 square yards area, the total area being 3848 square yards. The sewage is distributed at the rate of 400 to 500 gallons per square yard in 24 hours, which is about 2,000,000 gallons per acre. The purification is said to be good.

A very interesting plant has been erected at Hyde and is now being tested by Mr. Scudder, of the Irwell and Mersey Commission, chemically-treated sewage, instead of septic-tank sewage, being used.

The experimental filter that was in use at Leeds at the time of my last visit was 24 feet in diameter and 10 feet high, septic-tank sewage, without being heated, being sprinkled over the top of the filter.

The effluent from the filter was not a clear liquid and contained quite a large amount of suspended matter. This suspended matter is said not to be putrescible, and owing to the large size of the individual particles, soon settles out. The amount of purification accomplished by the filter running at the rate of 1,000,000 gallons per acre was good. The effluent at Leeds, after the settling out of the suspended matter, shows a purification of 92 per cent. in albuminoid ammonia and 93 per cent. in oxygen consumed on

the crude sewage, and 84 per cent. and 87 per cent., respectively, on the septic-tank effluent. The amount of nitrogen in the effluent as nitric nitrogen is from one to two parts in 100,000. More or less trouble was caused by the clogging of the surface of the filter by suspended matter and vegetable organisms. This hindered good aeration and necessitated frequent and periodic forking over of the top layers. The effluent appeared to contain so much suspended matter that it would have to be passed through a sedimentation basin before being run into the water-course.

The sprinkling arrangement, though automatic, required attention, owing to stoppage of the small holes by suspended matter. Further, in winter it would seem, on account of the openness of the filter, to be absolutely necessary to warm the sewage, and as I have stated, Mr. Whittaker claims that better results are obtained at all times if this is done. This of course adds greatly to the expense of the process.

A form of continuous filter that has attracted much attention in England during the past year is the Stoddart filter. (Fig. 8.) The filter itself is made of any hard, jagged material, as coke, hard-burnt cinder, iron slag, ranging in size from two to three inches and from which all finer material has been carefully removed. The floor of the filter is made of cement concrete, with a fall of one inch in three feet from the center to the collecting channel, which surrounds but lies entirely outside the filter. No channels or pipes of any kind are laid within the filter or on the floor.

As no liquid collects within the filter, retaining walls are unnecessary, and the sides of the filter can be made of large pieces of the filling material with a slight batter to increase solidity. If it is considered desirable to inclose the filter, the retaining wall is placed inside the collecting channel and is built on short brick columns in order to allow the ready escape of the effluent. The three essential points in the construction of the filter, according to Mr. Stoddart, are the arrangement of the floor, the uniform grade of the filtering medium and the freedom of the latter from dust or fine particles.

The distributer invented by Mr. Stoddart is in principle very simple. It is made of zinc or galvanized iron and consists of a number of perforated gutters, eleven in each section, 2 inches wide and 1½ inches deep, arranged at right angles to the supply channel. The perforations are cut in diamond shape at intervals along the upper edge of the gutters. On the under surface of the gutters are a number of small points, 360 to the square yard. The distributer rests upon the margin of the supply channel and upon suitable supports at the further end, and must be perfectly level to

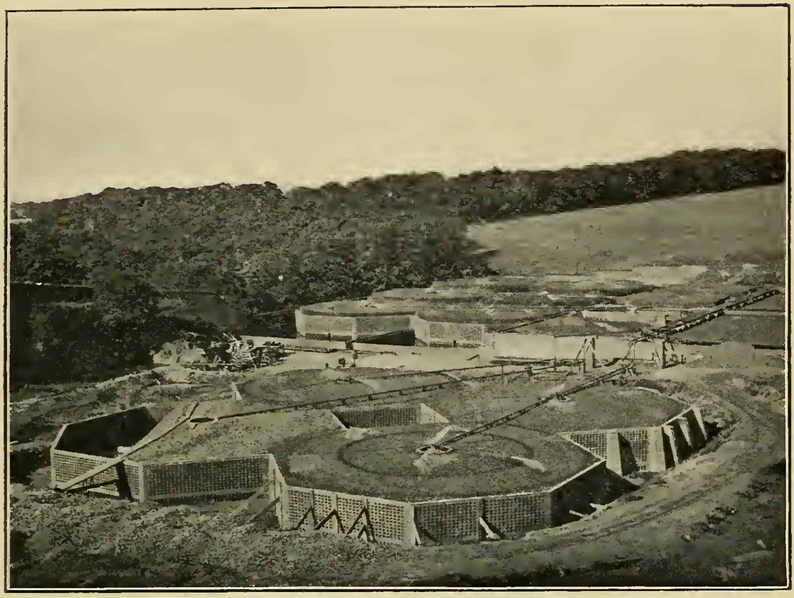

Fig. 7. The Whittaker & Bryant Filter, Church, near Accrington, England, 1900.

Fig. 8. The Stoddart Continuous Filter, Horfield, near Bristol, England, showing Construction, 1901.

secure equal distribution. The clarified sewage flows from the supply channel into the gutters and over the gutters through the diamond-shaped perforations and falls from the small points in a series of drops.

A filter such as described, Mr. Stoddart claims, will successfully treat clarified sewage containing about 0.5 parts albuminoid ammonia per 100,000 parts at the rate of 500 gallons per cubic yard per day, or in a filter 6 feet in depth each square yard of surface will deal with 1000 gallons, equaling 4,840,000 gallons per acre; and further, that the more diluted the sewage is with rain-water the greater can be the rate of filtration, and that the plant at Bristol, when the sewage was diluted with storm water, has frequently run at the rate of 30 to 40 million gallons per acre per day for several hours in succession. This of course would do away with all necessity for storm filters. The cost, according to Mr. Stoddart, is 35 to 40 shillings per square yard six feet deep.

Small plants have been built at Knowl and at Harfield, Bristol, and I believe at several other small places, and experimental plants are now being tried at Manchester and Leeds. I hardly know what to say of this method. I have carefully examined the plant at Knowl, Bristol, and the experimental filters at Manchester and Leeds. The filter at Bristol was running, at the time of my visit, at the rate of 5,000,000 gallons per acre; there was very little appearance of organic matter on the surface of the filter, and the filtrate was clear and without odor. The analysis of the filtrate that had been made showed that it was not putrescible. The albuminoid ammonia had been reduced from 0.5 to 0.13 parts and the nitrogen as nitric nitrogen equaled 1.48.

The experimental filters at Manchester and at Leeds have not given nearly as good results. The one at Manchester does not give a clear filtrate, and, when running at the rate of 360 gallons per square yard, 1,800,000 gallons per acre, a number of samples were putrescible. Mr. Stoddart claims that the construction at Manchester is faulty; that on two sides the filter was surrounded by earth to the height of about 2 feet, preventing aeration. Since my visit this earth has been removed and the experiments are being continued.

Considerable difficulty must be experienced in insuring regular distribution. The plates must be kept perfectly level and all buckling prevented. Further, if the clarified sewage contains any amount of suspended matter, this will settle in the gutters in a very short time, necessitating continual cleaning of the gutters.

The same difficulty with this filter as with the Whittaker-Bryant filter must be experienced in winter, and in the winter cold of New England I should expect the filter at times to be completely coated over with ice. It is, however, on account of the very high rate at which it is claimed it can treat clarified sewage, a method that is well worth attention and study.

By far the most interesting experiment I know of on continuous intermittent filtration is the plant now nearing completion at Salford, England, built according to the plans of Mr. Joseph Corbett, Borough Engineer. (Fig. 9.) At this plant the sewage of a city of about 250,000 inhabitants, with a dry-weather flow of sewage of over 8,000,000 gallons, is to be treated by this comparatively new method.

At this plant the sewage is first to be treated chemically and the clarified sewage run through roughing filters filled with gravel at the rate of 4000 gallons per square yard, the rate to be increased up to 16,000 in stormy weather. From the roughing filters it is to flow by gravity to the valve chambers and be delivered on the aerating bed.

This bed is 500 feet long, 510 feet wide and 10 feet deep and filled with cinders passed by a $\frac{1}{2}$-inch and rejected by a $\frac{1}{8}$-inch mesh.

From the valve chambers run two delivery mains 30 inches in diameter. One of these is connected with seven horizontal pipes, the other with eight. These pipes run the whole length of the bed, dividing it into sixteen sections, and the flow in each pipe is controlled by a valve. From each of these fifteen pipes are raised vertical pipes 10 feet apart and 10 feet high. Each of these stand pipes is connected at right angles with 4-inch horizontal pipes which run across the bed. On the top of the bed, therefore, there is a layer of horizontal pipes 10 feet apart. These horizontal pipes are fitted with vertical spray jets at every 5 feet, each spray pipe having two $\frac{1}{4}$-inch holes set at an angle toward each other.

The floor of the filter has a fall of 2 feet from inlet to outlet, and is covered with tiles raised on feet sufficiently high,—about 3 inches,—to insure air circulation beneath the filter. The drains are underneath the fifteen large horizontal pipes at the bottom of the chamber, and all discharge into a main culvert which carries the filtrate into the river.

The sewage passes from the valve chamber into one or both of the mains and is delivered to any or all of the horizontal pipes. From these it passes up the vertical pipes into the 4-inch horizontal pipes and then into the spray pipes. There is a sufficient head to cause the liquid to spout out of the spray pipes to a height of from

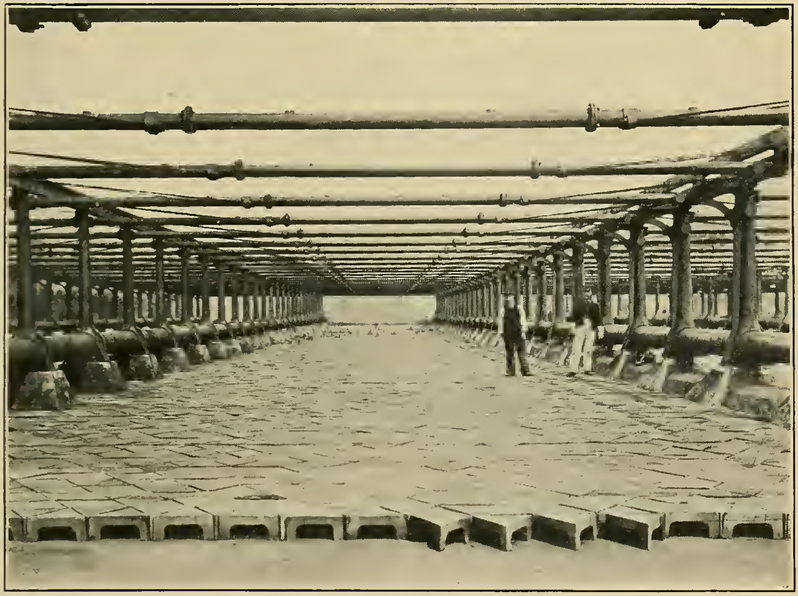

Fig. 9. The Corbett Filter, Salford, England, showing Construction, 1901.

5 to 8 feet, and it will then fall like rain on the surface of the filter.

The dry-weather flow upon the bed is to be about 500 gallons per square yard, to be increased, when necessary, to 1000 gallons.

There is no question that the construction of this plant is costly, but it seems to me that the chances of successful treatment are greater with Mr. Corbett's plant than by any other method of continuous filtration I have seen. The plant should be in full operation this year, and the result will be very instructive whether it is a failure or a success.

Intermittent continuous filtration is able to treat larger quantities of clarified sewage on a given area than any other bacterial process, and it has the advantage over the contact method that the accumulation of solid matter in the filter does not reduce the volume of liquid which can be treated until the amount of solid matter in the filter interferes with free passage of the liquid, which condition may be found never to occur. In conclusion I can only say that, though believing in the principle involved in the continuous filtration of sewage which has been acted upon by anaerobic bacteria, I do not think it is as yet a method which can be considered as practical, especially on a large scale and in a climate where the winter temperature is similar to that of New England.

## Discussion.

Mr. Leonard Metcalf.—I had hoped that some of our older members would open the discussion upon this very live topic.

Dr. Kinnicutt has presented to us a most interesting and well-balanced paper upon the subject of the later developments in the bacterial treatment of sewage, and he has summed up in a very fair-minded way the recent work which has been done in England along the different lines or methods of sewage disposal.

Certain facts, however, must not be lost sight of. Foremost among these, that the English results must be interpreted from the point of view of English conditions and environment, rather than from our own.

The sewage which the majority of English plants have to deal with, as compared with the characteristic sewage of this country, is much more concentrated; hence high rates of filtration are possible only after some form of primary treatment or preparation.

The question of climatic conditions may play a very important part in the efficiency of the plant. It seems to me that in such a latitude as ours, the method of continuous filtration, if practiced along the lines now being experimented upon in England,—that is, by uniform distribution of the sewage over the surface of the bed

by means of a spray or jet,—appears impossible, for in our colder weather the applied sewage would soon form a solid sheet or coat of ice upon the surface of the bed. Similarly, the Stoddard filter would be impracticable in our latitude during the winter months, for, aside from the probable clogging of the drip holes in the trough distributers, there is the difficulty of freezing and of keeping the various parts of the distributer in alignment, so that the distribution will be uniform, for it is evident that one of the essentials to high rates of filtration is the perfect application and distribution of the sewage upon the beds.

Of course the engineer has many different conditions to meet in practice. Thus, in a large city the problem is quite different from that of a small plant, such as a manufacturing plant or that for a small town, and methods of sewage disposal which are practicable for the one are not necessarily so for the other. The larger the areas, the more difficult the proper application or distribution of the sewage over the disposal areas. Hence any reduction in the area of beds required diminishes the difficulty of obtaining proper distribution.

The question of supervision is a very serious one, and, indeed, one which will often decide the question as to the type of disposal works to be used. In my own practice I recall two or three cases in which contact beds would have been advisable had it not been for the danger which would have resulted from inadequate supervision over the plant in operation. One great difficulty lies in obtaining automatic discharge of doses of sewage successively on different beds. There are several automatic devices in the market for accomplishing this, which are said to have given good satisfaction, but even they must be inspected from time to time. Messrs. Snow and Barbour, members of this Society, have designed such a device, which, I understand, is in successful operation at the Danvers Insane Asylum, and, perhaps, elsewhere; and, more recently, Messrs. Alvord and Shields, of Chicago, have made use of a different type of mechanism at Wauwatosa, Wis. These devices are, perhaps, expensive for small plants; in larger plants the relative expense is, of course, smaller; moreover, in the latter constant supervision becomes necessary for other reasons.

The tendency in the construction of contact beds in England at the present time to make use of a finer grade of material, than that constituting the bulk of the bed, upon the surface of the bed is certainly worthy of note, and appears to be a step in the right direction, as the finer material may readily be scraped and replaced from time to time, thus maintaining the capacity of the bed itself.

Of course this method of construction is intended only for contact beds, and not for intermittent filter beds, such as have been so largely used in this vicinity.

The difficulty of obtaining a normal sample of sewage has an important bearing upon the question of the degree of purification obtained by the use of septic tanks and the apparent discrepancies in the chemical analyses of the raw sewage and the effluent from the tank. This is particularly so in the case of small plants with short pipe systems. If a suitable receptacle can be obtained for holding a considerable amount of sewage, and if samples can be taken therefrom at frequent intervals during the day, a fairly good result may be obtained; but the method of taking samples from the drains as the sewage passes through them is, to say the least, very unsatisfactory, for it results in untrustworthy analyses of the raw sewage, and hence in anomalous results in the comparison of the raw sewage and the tank effluent.

The septic tank does not do away with the sludge problem, which is, after all, the vital problem in sewage purification. It does mitigate the sludge nuisance, but, unfortunately, the sludge which is produced, though smaller in amount, is generally far worse in character than that resulting from other methods of treatment. Where the sludge can be carried to sea and thus disposed of, it makes little difference, but when the sludge itself remains to be treated, the handling of large quantities of it becomes a serious problem.

Attention should be called to the dearth of definite information concerning the proper period of contact for the sewage in the septic tank. English practice has favored a period of from twenty-four to thirty-six hours, while American practice has tended toward considerably shorter periods. The character of the original sewage and the length of what might be termed the period of delivery will doubtless control this largely, though climatic conditions must also have an important influence.

This brings us to the question of the degree of purification required, and suggests as most promising fields for the use of the septic tank and contact beds not only those localities where suitable materials of construction are expensive, but also those places in which partial purification only—that is, the securing of a non-putrescible effluent—is required. That the septic tank and contact beds are promising methods of sewage disposal is evidenced by the large number of sewage-disposal companies that have recently been organized and that are operating under various patents; but it is certainly unfortunate that the progress of the science of successful

sewage disposal bids fair to be seriously impeded by patent considerations and the possibility of legal entanglements. The writer understands that already in the case of one city, where some most valuable experiments upon the disposal of the city's sewage are being conducted, has concluded not to publish further results obtained from the septic tanks on account of the attitude and claims of certain companies controlling septic tank and contact bed patents,—patents upon the validity of which the courts have, however, not yet been given an opportunity to pass.

The writer is of the opinion that the various patent claims upon the broad principle of septic tank treatment will not stand the test of the courts. On the other hand it is probably true that certain of the mechanical appliances or devices connected with the tanks are original.

Some of the patent considerations involved have been discussed by the writer in an article upon the "Antecedents of the Septic Tank," Transactions of the American Society of Civil Engineers, Vol. XLVI, 1901.

Professor Wm. T. Sedgwick.—At the outset I desire to express publicly the sense of personal obligation which I feel to Professor Kinnicutt for the very able and interesting paper to which we have all just listened with so much pleasure. For the second time, he has now brought to us the rich results of his expert personal observation and study of the modern English theory and practice of sewage disposal, derived from a careful examination of local conditions in a large number of typical English cities and towns. Anyone who has ever undertaken, as I have once or twice done, to make visits of this character, to collect the true facts, to make fair comparisons, and especially to draw just conclusions and to forecast the future, knows well how laborious, how tedious and how costly such effort is.

From my own point of view, namely, that of bacteriology, all these processes about which we have been hearing to-night are extremely interesting. In the so-called "septic tank" we have a sewage purifying itself as it were, or "working," like apple juice when the latter is being fermented in a cask by wild yeasts. Everyone is familiar with the process of cider-making, in which sweet apple juice charged with microbes derived from the dust on the skin of the apples, or from the straw, or from the atmosphere, or from the walls of the cask is slowly "worked" over by the microbes present, and especially by wild yeasts, and turned into hard cider or eventually by vinegar microbes into vinegar. In a similar way fresh sewage charged with microbes may be "worked" over by its

own microbes and is so worked over or "fermented" or "putrefied" in a cesspool or a septic (*i.e.* putrefaction) tank. I believe that as a means of partial self-purification of sewage the septic or putrefaction tank has come to stay; but that it will ever take the place of the complete purification accomplished by intermittent filtration through sand I do not believe, for the reason that only in the latter process do oxidations appear to be completely carried out.

It is very interesting, as well as somewhat amusing, to see how the old-fashioned cesspool,—which pseudo-sanitarians have long despised and condemned, but the value of which has been well understood and appreciated by scientific students of sanitation,—has at last been exonerated from suspicion and vindicated in its reputation, and how under a new name it has become the popular "septic tank" of to-day. One of my students only a day or two ago opened a so-called cesspool belonging to a sanitarium near Boston and found it in every respect, except name, a perfect septic tank, having a crust some eight inches thick on the top, and with everything working as well as could be desired in any septic tank specially constructed.

The introduction of the septic-tank system (which may well be called the partial "self-purification of sewage") as a recognized element in sewage purification, worthy of careful study and employment, is, I think, a great advance; and even if it shall prove to be no more than a vindication and further application of the cesspool, it will play in the future an important part in sewage disposal, especially for separate houses, institutions, sanitariums and the like. When once we come to know more of its bacterial operation, and especially of the fate of disease germs in the septic tank, I think we shall value it even more highly than we do to-day.

With regard to double-contact beds, I have always been more skeptical. I visited Colonel Waring's plant when it was at work in Newport, and while the theory of it was fairly good, it never seemed to me to be as good as he thought it was. His theory was this: In intermittent filtration we get only so many hours a day of work out of the bacteria, and if we could work them all day we should probably get better quantitative results. Here it seems to me was the fallacy, for it does not follow that if we work a man twenty-four hours a day we necessarily get more out of him than if we work him only ten hours. Of course bacteria are very different from human beings, and yet I think that it is not difficult to see how the double-contact beds may lose their liquid capacity if treated on this system because of bacterial growths. For what we want is to get the bacteria to clean up the last part

of the sewage, which is always the poorest part and for them the poorest food. Now if they have plenty of the richer, better part they will often not take the trouble to feed upon the poorer part. They are likely to devour only the better food and let the poorer go. These statements are not based upon analogy merely, but upon well-known facts in the nutrition of the lower micro-organisms, and I do not think that when bacteria are well fed for twenty-four hours, or any large part of it, they are likely to oxidize efficiently the last (*i.e.* the most refractory) portions of the sewage, which are poor food for bacteria; and I do think that they are very likely to multiply enormously upon the abundant richer portions, perhaps passing into that jelly stage which is a part of their life history, settling down, as it were, and, like stall-fed oxen, growing fat and doing very little work. I throw this idea out merely as a suggestion; but I would be almost willing to predict that in those contact filters which lost their liquid capacity and became stopped up, the sewage was less purified,—that is, was richer in food for bacteria before it went upon the filter,—than was the case in those filters which remained comparatively open.

In making observations such as Professor Kinnicutt has been making in England, one learns some interesting and valuable but unexpected lessons. I have in mind one which was taught to me a year ago last summer while talking with the City Engineer of Oxford, where I was working for a few weeks, about the sewage disposal of that ancient university city. The system of disposal employed in Oxford is irrigation, and I remarked to the engineer that of course the rainy climate with which he had to deal added materially to the difficulties of getting rid of the sewage upon land. But he replied, "O, no! we do not have nearly as much rain as you do in Boston." "Is that so!" I exclaimed; "what is your annual rainfall?" He replied, "About twenty-five inches." Now the ordinary traveler in England and on the Continent or the reader of English literature certainly gets the impression that England is a very wet place, and so it is,—but the wetness is in the air rather than in the ground. In other words, although England really has a very moist, damp climate, heavy rains such as we frequently experience are almost unknown, and I was very much surprised, as well as interested, to learn that the rainfall of Oxford is only somewhat more than one-half that of Boston.

I think that we ought to feel especially indebted to Professor Kinnicutt for digesting and reporting to us so thoroughly and acceptably as he has done the theory and practice of our English friends at the present time concerning sewage disposal, but even

more important it seems to me is the original work which he is doing upon this same subject at the purification works of the city of Worcester and in his own laboratory; and we shall await with the utmost interest the conclusions to which he may come concerning the efficiency of the self-purification of sewage, by the septic tank; the contact filters, whether single or multiple; and even the continuous filtration of sewage,—although this last I must confess seems to me too much like Colonel Waring's Newport experiment—interesting in theory, but of very doubtful expediency or value in practice.

Mr. Frank A. Barbour (by letter).—The Boston Society, and particularly those members engaged in sanitary engineering, must acknowledge a debt of gratitude to Professor Kinnicutt for his valuable paper. Without question, the present status of the sewage problem in England has been examined with unprejudiced vision and described in the light of an intimate scientific knowledge of the subject. This gives to the paper a distinct value for American engineers, because, unfortunately, in England proprietary methods have been, in many cases, more largely responsible for the optimistic claims put forward than calm study of the premises and results, and it has accordingly been difficult, from this side of the water, to distinguish the relative merits of these claims.

Degrees of purification and rates of operation have been announced which only a few months' trial were necessary to disprove. Analyses of the untreated liquid and of the effluent, with the samples collected in such a way as to be fairly expressive of the results, have been seldom given out, and thus it is that English experience may, perhaps, better serve to indicate the general trend of the development of high rate purification by bacterial methods than as the actual basis of design. In studying the description of the various systems one cannot but feel that, impelled by the hope of financial profit or by the urgent necessity of meeting difficult conditions in the centers of population, there has been a rush to devise new methods—different from those preceding—almost in some cases to the extent of adopting the fantastic.

The keynote of the paper is that to-day the problem is far from finally settled, and that many of the most important factors are as yet indeterminate. In relation to the septic tank we are told that it is dangerous to prophesy as to the odor from any particular installation; that, up to the present time, there is no rational way of adapting the period of exposure to the quality of the sewage. As to the most effective depth, the relation of depth to area, whether the tank should be divided transversely so as to conform

the greater portion of the solids in the first compartment, but little is definitely settled.

Some means of knowing the optimum period of septic exposure for a particular sewage is most desirable. That there is a minimum time below which liquefaction will not occur is certain, that twenty-four hours is long enough for ordinary sewage has been proved by experience, and that the necessary time is some function of the strength of the sewage has been shown by experiments on the septic treatment of sludge. The adoption of a capacity equal to the twenty-four-hour flow, with, perhaps, automatic weirs to equalize hourly variation, and the division of the plant into a number of units, so that one or more can be cut out, if necessary, would seem to be the present reasonable basis of design. Where the sewage is weak, or where, as in summer resorts, the maximum comes in the warmer months, a lesser capacity is probably justifiable.

The septic tank has apparently proved its right to exist as a means of preliminary treatment, but as to the value of contact beds, opinion is more unsettled.

Contact beds were originally adopted as a means of extending the area of effective bacterial activity and consequently the rate of operation, by using a material so coarse that, without mechanical apparatus, greater quantities of air would enter the body of the filter. The beds were to fill with air between doses and the action was to be aerobic. Experiments, however, have shown that the action between doses is largely anaerobic and that air does not enter so much between doses as with the sewage during its inflow. The method of dosing is, therefore, most important.

By the general method of applying the sewage, now employed, a continuous current is flowed into one of the sections of the contact beds, until the bed is filled to the desired height. It would seem that perhaps intermittent dosing in quick, short flushes with distributers arranged to thoroughly spread the liquid over the surface of the bed might profitably be adopted. In this way the action of the bed during filling would resemble that of a continuous intermittent filter, and if the contact beds were only filled to a portion of its depth, the upper part, not backflooded, would be equivalent to such a filter. At Mansfield, Ohio, the dosing apparatus is so arranged that the beds can be handled in this way.

As contact beds are generally operated at present, the action is both aerobic and anaerobic—with perhaps greater dependence on the results of the latter condition. At first thought it would seem best to draw a sharper line between these two conditions and to

attempt to complete the anaerobic purefaction in the septic tank, making all subsequent action one of oxidation and nitrification. With the septic tank better understood, it ought to be possible to turn out an effluent thoroughly liquefied and ripe for final purification by aerobic action.

It has been pretty well demonstrated that raw sewage cannot well be treated in contact beds and the liquid usually applied to these beds is septic effluent. Such a liquid greedily absorbs oxygen and, if introduced into a contact bed in the same condition as it issues from the septic tank, the resulting action can be little more than a straining of the liquid under anaerobic conditions. Thorough aeration would seem to be a necessary preliminary to the application of septic effluent to contact beds. Whether inadequate aeration may account for the reduced rates, now claimed for this method of filtration in England, does not appear from the paper.

Unquestionably the greatest danger in the use of contact beds is the accumulation of matter in the interstices of the material.

At Manchester it is proposed to intercept the suspended solids by a surface layer of fine material, but it would seem that this layer would also prevent the entrance of air and that a better method would have been to limit the fine material to a small area around the outlets, depressing the surface covered by this material so as to form a pool three inches deep, across which the liquid would flow with a slow velocity and enter the coarse material of the bed surface beyond. This is the method used at Mansfield, Ohio, and suggested by the conditions at Marion, Iowa, where a septic effluent runs from the tank to the stream over the ground, leaving a slight deposit near the tank and reaching the stream comparatively free from suspended solids.

It is to be noted that many of the English contact beds have been constructed with materials, the particles of which vary greatly in size, little attention having apparently been paid to mechanical analyses and the advantages of greater air space and less settlement, to be gained by using a material more uniform in size of particle. In a plant recently constructed by the writer at Mansfield, Ohio, locomotive cinders were used—at Lakewood, Ohio, cinders from a manufacturing establishment. In both cases the material was crushed and screened—the final product being the most vitrified portion of the cinders and varying in size from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch. The cost per cubic yard placed in beds amounted to about 85 cents—about one-half of this representing labor in crushing and screening, the other half the cost of purchasing and transporting the cinders. About 85 per cent. of the volume of the raw

material was recovered as final product, while the waste amounted to 35 per cent. of the raw material.

The discussion of continuous intermittent. filtration is extremely interesting and valuable—not only because this system apparently holds the center of the sanitary stage in England at the present time—but also because its success is due to a recognition of the necessity for proper methods of dosing, a necessity which has been in this country considerably neglected, both in the carrying out of experiments and in practical work. To repeat an oft-repeated sanitary axiom—successful purification by filtration depends on oxygen and time. The sewage must be held in contact with the bed and in the presence of sufficient oxygen for a time long enough to complete purification. A logical deduction is the use of the coarsest material which can be so dosed as to meet the necessary condition of time, and thus the intermittent continuous filter has come into prominence.

With ordinary sand filters, however, the method of dosing is most important. As in the case of contact filters, air enters with the sewage rather than between doses; the filter is between doses largely filled with carbonic dioxid. During the flow of effluent from beds, the gas driven out into the underdrain manholes by the advancing liquid, at Brockton, has at times been so largely carbonic dioxid as to seriously affect the assistant collecting samples.

The advantage of intermittent dosing in quick, short flushes is easily apparent—not only because in this way greater quantities of air are carried into the filter, but also because no head or pressure is thereby brought on the sand, and the liquid passed through too quickly. In several plants observed by the writer, the effluent will start in a strong flow fifteen to twenty minutes after the application of a dose of 80,000 to 100,000 gallons on an acre bed—with the drains at a depth of six feet. In such cases the quality of the effluent during the first part of the discharge is much below the average—proving that the effluent which first appears is not that previously held in the sand, but a part of the dose immediately applied. Whether it is advisable to adopt the elaborate devices for applying sewage to filters now so popular in England, is a question, but there can be no doubt that a valuable lesson may be learned from the continuous intermittent system,—namely, the desirability of providing better means for applying the sewage in doses proportioned in size and rate of application to the area of the bed.

The use of coarse material in the continuous filter necessitates the adoption of complicated dosing apparatus which in the cold winters of this country would be difficult to maintain.

In a recent series of analyses, made by the writer, of the applied sewage and effluents from a sand filter provided with an aerating layer of gravel and air pipes at mid-depth, it was found that extremely high rates could be successfully maintained and the influence of the aerating layer in promoting nitrification was markedly shown by comparison of samples of effluent taken above and below this layer. It is believed that where filters are to be artificially constructed, much higher rates, than have yet been attempted in practice can be obtained by improved methods of dosing and subsoil aeration, and this without the necessity of using dosing apparatus difficult to operate in winter.

There is one phase of the status of sewage disposal in England to which perhaps, it will not be amiss to call attention,—namely, the standard of purification demanded by the authorities and obtained by the systems now in vogue in that country. Professor Kinnicutt has referred to the Irwell & Mersey standard which calls for an albuminoid ammonia not exceeding .14 part per 100,000 and an oxygen consumed not exceeding 1.40 parts per 100,000. This is equivalent, on the basis of the albuminoid ammonia to the liquid which would result by diluting ordinary raw sewage with six times its volume of water. In this country it is generally considered that at least 2.5 cubic feet per second of water per 1000 people contributing sewage, or a dilution of forty times is necessary to prevent a nuisance in the stream.

It is evident, therefore, that one of the first requirements in order to understand the present status of sewage disposal in England, is an appreciation of the quality of effluents with which authorities there are satisfied. This lower standard is the explanation of many of the systems proposed, because, neither by contact beds nor continuous filters, operated at righ rates, can such degrees of purification as are usually obtained from intermittent sand filters be economically obtained. Cinder filters, five feet deep and properly equipped will cost from $10,000 to $25,000 per acre, and, if a high degree of purification is demanded, the necessary area will be such that the cost will, except under unusual conditions compare unfavorably with that of sand filters.

The adoption of a lower standard of purification in a thickly settled country is natural. All streams must serve to a certain extent as carriers of waste matters and neither legally or logically can it be expected that the water will continue to flow as it is "wont by nature." Recognizing this, it is reasonable to accept an effluent adapted to the stream conditions—not attempting the transformation of sewage to drinking water, but insuring that no

nuisance will be created. In this direction lies the greatest field for the use of high-rate bacterial methods of sewage purification.

Mr. George A. Carpenter (by letter).—I have been very much interested in Professor Kinnicutt's paper, and especially in that portion relating to the action of the septic tank and contact filters.

The results obtained with an experimental tank of about 68,000 gallons capacity, which I have been operating at Pawtucket, R. I., for two years, accord very closely with those reported for Leeds. They are as follows:

Parts per 100,000.

| | Raw Sewage. | Septic Effluent. | Per Cent. Removed. |
|---|---|---|---|
| Total solids | 92.46 | 59.33 | 35.84 |
| Soluble solids | 54.09 | 47.23 | 1.25 |
| Suspended solids | 38.37 | 12.10 | 68.46 |

The average amount of albuminoid ammonia removed by the septic tank was 41.3 per cent. on the first experiment of ten months' duration, and 42.7 per cent. on the second experiment, which continued eight months and eighteen days.

I agree with Professor Kinnicutt that the amount of sludge which the septic tank is capable of decomposing has been generally overestimated. Results in Pawtucket have shown that 47 per cent. of the solids retained in the septic tank were septicised on the first experiment and 38.3 per cent. on the second. Figured on the percentage of suspended solids, the 38.3 per cent. becomes 48 per cent.

The amount of sludge collected on the first experiment was 5.428 cubic yards per million gallons of sewage passed through the tank, and, on the second, 4.846 cubic yards. In the first case the percentage of moisture of this sludge was 81.75, and in the second, 79.11.

The reduction of the sludge to absolutely dry matter makes .99 cubic yards and 1.012 cubic yards per million gallons for the first and second experiments respectively. The average amount of sludge removed from the sand beds during the treatment of the sewage by sedimentation and filtration, over a period of six years, averaged 3.14 cubic yards per million gallons of sewage. The sewage is now stronger than formerly, and from August 7 to October 1, 1901, the sludge averaged 4.87 cubic yards per million gallons.

It is greatly to be deplored that, from the numerous septic tanks installed in the United States, hardly any records of the character and composition of the sewages treated are available.

It is of little value to state that in a particular tank "there has been no noticeable accumulation of sludge," or that "there has been very little deposit in the septic tank," unless some average analyses of the sewage treated, and of the effluent from the tank, accompany such a statement. And, even in cases where these can be given, it is also necessary to record the amount of the sewage which has passed through the tank in a given time and to make a measurement of the sludge deposited. The generalized statements of the past have led engineers to believe that the septic tank was capable of accomplishing more work than a thorough investigation has revealed.

Considerable interest and value would, I think, be added to the table of "Solids in Sewage and Septic Tank Effluent," given by Professor Kinnicutt, if it could be carried farther and the total accumulation of sludge in the septic tank could be shown.

Using his estimate that "the amount of sludge decomposed does not usually exceed 30 per cent. of the total suspended matter arrested in the tank," I have prepared the following tables, indicating the final disposition of the solids of the sewage. They are based upon an arbitrary outline suggested by Mr. Geo. W. Fuller, and are interesting as an attempt to separate and compare the work of different tanks.

The figures given for Pawtucket have been obtained by actual measurement.

TABLE I.

PARTS PER 100,000.

| | SUSPENDED SOLIDS. | | | | Total Solids in Raw Sewage, Excluding Amount Dissolved in Septic Effluent. e. | Solids Gasified = e − (b + c + d). f. |
|---|---|---|---|---|---|---|
| | In Raw Sewage. a. | In Tank Effluent. b. | Decomposed by Septic Tank. Figured as 30% of a and b. c. | Balance Left as Sludge. d. | | |
| Exeter | 35.00 | 15.40 | 5.88 | 13.72 | 33.90 | — 1.10 |
| Leeds | 47.60 | 14.10 | 10.05 | 23.45 | 56.70 | 9.10 |
| Manchester | 37.15 | 15.95 | 6.36 | 14.84 | 51.72 | 14.57 |
| Worcester | 20.06 | 17.90 | 0.65 | 1.51 | 34.51 | 14.45 |
| Pawtucket | 38.37 | 12.10 | 5.73 | 20.54 | 45.21 | 6.84 |

TABLE II.

| | | Exeter. | Leeds. | Manchester. | Worcester. | Pawtucket. |
|---|---|---|---|---|---|---|
| Total Solids in Sewage, Excluding Amount Dissolved in Septic Effluent... | | 33.9 | 56.7 | 51.72 | 34.51 | 45.21 |
| Percentage Distribution of the Solids of the Sewage. | Tank Effluent (Col. b.) | 45 + | 25 — | 31 — | 52 — | 27 — |
| | " Sludge ( " d.) | 41 + | 41 + | 29 — | 4 + | 45 + |
| | " Liquefied ( " c.) | 17 + | 18 — | 12 + | 2 — | 13 — |
| | " Gasified ( " f.) | — .03 | 16 | 28 | 42 | 15 |
| | | | 100 | 100 | 100 | 100 |

This attempted comparison clearly indicates the need of more detailed information than we yet possess, to enable engineers to predict the results which may be expected from the passage of a particular sewage through a septic tank.

The more the question is studied, however, the more evident it becomes that, no matter what the method of disposal may be, there will always be a considerable amount of sludge that must eventually be disposed of. The amount of this sludge will depend largely upon the amount of suspended matter in the original sewage.

My experience would seem to indicate that this sludge can best be disposed of, through the summer at least, by sedimentation and intermittent filtration through sand beds. By this method the sludge loses a large percentage of its moisture, and can be readily raked from the surface of the sand and then burned, used for filling or be plowed into fields that are to be cultivated.

Through the severe winter weather, when sludge will freeze on the sand beds and will not dry out so that it can be raked off, the septic tank may be used with profit. The sludge will be retained in that, will decompose to some extent, as indicated by the table, and can, as spring approaches, be taken from the tank and disposed of.

Another difficulty which arises, when trying to compare the results of several septic tanks, is the failure of experimenters to note whether the crude sewage is screened before passing to the tanks, and, if it is, what is the amount and disposition of these screenings.

In the comparison of water works systems, some uniform method of recording data had to be provided, and so, it seems

to me, some uniform system of gathering and recording the facts regarding sewage disposal systems must be adopted before we can hope to obtain the fullest information and an intelligent comparison of results.

PROFESSOR KINNICUTT (by letter).—I wish first of all to thank the various speakers for their kind remarks and for the favorable consideration they have given to my paper.

As to the septic tank, I think Professor Sedgwick's comparison to the fermentation of cider and the term "self-purification of sewage" are most happy, and they show to us in a very few words what is the essential action of the septic tank.

Mr. Metcalf calls attention to the fact that, as a rule, English sewage is much more concentrated than the sewage of most American cities, and that high rates of filtration are applicable there only after some form of preliminary treatment. I think that, though American sewage is less concentrated than English sewage, it is not a wise plan, as a rule, to run crude sewage directly upon sand-bed areas if the rate of filtration is to equal anything like 100,000 gallons per acre per day. I am very sure that much better results could be obtained with intermittent filtration beds if the cellulose and nitrogenous substances had been partially decomposed by an anaerobic bacteria before passing the sewage upon the beds, for the action of the sand beds should be mainly aerobic and not anaerobic.

Mr. Barbour expresses very tersely the numerous unanswered questions concerning the action of the septic tank and shows how much still remains to be determined. His change of construction of the septic tank so that the rate of flow can be regulated is certainly an improvement over the older forms.

All the speakers agree that the septic tank is only a preliminary treatment, and does not do away with the sludge problem, and I am glad to see that Mr. Carpenter agrees with me in that the amount of solid matter which is liquefied or changed into gas has been usually overestimated.

As to contact beds, I agree in a great part with what has been said by the various speakers. The action should be aerobic, and the greater the amount of air admitted to the beds, the more perfect should be their action. If the surface becomes coated, or the voids filled with solid substances, the capacity of the bed must be diminished. The clogging of a contact bed is caused, to a great extent, not by applying too much food material, but by applying food material in a form that the aerobic bacteria cannot assimilate. Giving organic matter in the form of proteids to aerobic bacteria,

it seems to me, is something like giving ground phosphate rock, as it occurs in nature, to higher forms of vegetable life. We change the phosphate rock by the action of sulphuric acid into soluble phosphate of calcium before using it as a fertilizer; so should the proteids be changed into simpler nitrogenous products by the use of the septic tank before giving them as food material to the aerobic bacteria.

I am very glad that both Mr. Metcalf and Mr. Barbour have called attention to the difference in degree of purification required in this country and in England, and it is true that a purification only equal to the Irwell and Mersey standard would often be considered inadequate in this country.

My own opinion as to the degree of purification is that it should not depend on the amount of albuminoid ammonia, the amount of oxygen consumed, the nitrogen as nitrites and nitrogen as nitrates contained in the effluent, though these data do give valuable information; but that the standard should be whether or not the effluent will undergo secondary putrefaction. This likelihood of secondary decomposition cannot be determined from the above factors, but from Scudder's Incubator Test. If a sewage effluent from any process gives continuously good results with the incubator test, it certainly seems to show that such an effluent cannot undergo secondary decomposition when run into a watercourse.

Continuous filtration methods, as Mr. Barbour remarks, are deserving of careful study, if on no other account, because they do call attention to the fact that the work which can be accomplished by bacterial beds depends largely on the manner in which the sewage is applied, and because they show the possibility of treating very large amounts of clarified sewage on comparatively small areas.

As I have said, these methods are still in the experimental stage, and all I have attempted to do this evening is to call attention to the different ways in which attempts are being made to render continuous filtration a practical method for the treatment of sewage.

# RAINFALLS.

By Alfred F. Théard, Member Louisiana Engineering Society.

[Read before the Society, March 10, 1902.*]

Gentlemen: In our city, with its semi-tropical climate, where changes of temperature of 30 to 40 degrees in less than twenty-four hours are recorded, I have thought that a short recital of facts concerning our local rainfall would prove of interest.

New Orleans is situated sufficiently close to a vast body of water to be classed as a coast city, and to be subjected to its atmospheric rules. Surrounded by an absolutely plane country, without protection by mountainous elevations, it is, indeed, interesting to compare actual records, inherent to atmospheric and climatic conditions, with those established by science and applicable to regions similarly situated.

I shall try, as briefly as possible, to explain some features of our rainfalls which have come under my personal notice during the several years of my connection with an office where a correct and reliable continuous record has been made; prefacing these remarks with the definition and explanation of the principles and general laws accepted as the result of scientific investigations.

This may prove instructive to some, and it has enabled me, in some instances, to make comparisons between our own records and the generally accepted theories, and to draw conclusions as to their correctness and applicability to our local conditions.

The scope of the subjects which I will necessarily mention, is so vast, that I have not attempted to amplify or explain the general laws enunciated. I will, therefore, state in a general way, the accepted theory of the cause of rainfall under its varied forms, a few phenomenal records established, and some local data in which we are concerned. In describing the phenomena which are the primary causes of atmospheric disturbances, it will be necessary to define and explain briefly, radiation, evaporation, condensation, mists, fogs, dew, frosts, snow and hail; and I have taken the definitions quoted from the best recognized authorities.

All phenomena noticeable in the atmosphere are referable to the action of the sun, for, as Professor Stewart says, "If the sun were blotted out from the sky, a cold lifeless uniformity would rapidly take possession of the whole surface of the globe."

These atmospheric phenomena are, therefore, divided into two classes, daily phenomena and annual phenomena, or those refer-

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able to the revolution of the earth on its axis and those dependent on its revolution around the sun.

The first and most important of the daily atmospheric changes is that of the temperature, to which all others can either directly or indirectly be referred.

The gaseous envelope surrounding the earth is composed of two atmospheres, quite distinct from each other: an atmosphere of dry air and an atmosphere of aqueous vapor. Dry air is always a gas and its quantity remains constant, but aqueous vapor does not continue permanently in the gaseous state and the quantity present in the air is, by the ceaseless process of evaporation and condensation, constantly changing.

If the aqueous vapor remained permanently and unchanged in the atmosphere, or were not liable to be condensed into clouds or rain, the mixture would become as complete as that of the nitrogen and oxygen of the air. The equilibrium of the vapor atmosphere, however, is being constantly disturbed by every change of temperature, by every instance of condensation, and by the unceasing process of evaporation.

Aqueous vapor is constantly being added to the air from the surface of water, snow and ice, from moist surfaces and from plants. The rate of evaporation increases with an increase of temperature, because the capacity of the air for vapor is thereby increased.

The atmosphere can only contain a certain definite amount of vapor according to the temperature. When, therefore, the air has its full complement of vapor, or when, in other words, it is saturated, evaporation ceases. Evaporation is greatest when the air is dryest, and least when the air is nearest the point of saturation. Currents of air remove the moisture and substitute dryer air over evaporating surfaces, and evaporation is much more rapid during wind than in calm weather.

Air expands under diminished pressure, its temperature naturally falls, and it approaches nearer to the point of saturation and becomes moister. It contracts under increased pressure, its temperature rises and becomes dryer and recedes from the point of saturation.

On clear and calm nights the temperature of the earth's surface is gradually lowered to the dew point, and when this point is reached the aqueous vapor is condensed into dew.

This cannot happen in cloudy weather because the clouds prevent the escape of heat by radiation; nor in windy weather because the wind continually renews the air in contact with the earth's

surface. When the temperature is at or near the freezing point dew becomes frost. Radiation is the constant interchange of heat among bodies exposed to each other. When one body receives more heat than it radiates, its temperature becomes warmer; when, on the contrary, it radiates more heat than it receives, its temperature is lowered.

Radiation from the molecules of the earth's atmosphere toward the cold regions of space, the simple expansion of the air of ascending currents, the mixing of cold air with air that is warm and moist, and the cooling of the air in contact with the surface of the earth, when its temperature has been lowered by nocturnal radiation, are causes that lower the temperature of the air.

When on clear and calm nights, owing to terrestrial radiation, the temperature of the objects on the earth's surface is reduced to a certain point, the aqueous vapor is condensed into dew on their surfaces.

Mists and fogs are visible vapors, floating in the air near the earth's surface; and clouds are visible vapors at a considerable height.

These visible vapors are formed by whatever lowers the temperature of the air below the dew point.

All storms are essentially the same, differing from each other only in their dimensions, intensity or the degree in which the moisture is condensed into visible vapor.

Whirlwinds, water-spouts, tornadoes differ radically from cyclones. The largest tornadoes are of so decidedly smaller dimensions when compared with the smallest cyclones as to admit of no shading of the one into the other.

Cyclones take place under conditions which involve unequal atmospheric pressures or densities at the same heights of the atmosphere, due to inequalities in the geographical distribution of temperature and humidity, but whirlwinds occur where for the time the air is unusally warm or moist, and where consequently temperature and humidity diminish with height at an abnormally rapid rate. Cyclones are thus phenomena resulting from a disturbance of the equilibrium of the atmosphere considered horizontally, but whirlwinds and tornadoes have their origin in a vertical disturbance of atmospheric equilibrium.

Hail, snow and rain are simply the manner and degree of precipitation accompanying storms. All hail is connected with whirlwinds more or less developed and it is when the hail storm is one of the phenomena attendant on the tornado or on a great thunder storm that it assumes its most destructive form.

The vapor carried aloft by the gyrations of the tornado is below a certain height condensed into cloud and rain, but above that height into snow. If the rain drops formed below be carried into the snow region by the powerful ascending currents of a tornado, and be kept suspended there a little while, they become frozen into hail. If they become separated from the gyrations of the tornado, they are precipitated to the earth as hail stones of clear ice.

Snow, in bulk ten or twelve times lighter than water, takes the place of rain when the temperature is sufficiently low to freeze the condensed moisture in the atmosphere.

When, therefore, owing to a cold current appearing in some part of the atmosphere the vapor which it contains cannot continue in its gaseous state, it becomes condensed, and in accordance with the conditions under which this condensation has been accomplished, rain, snow or hail is produced.

Whatever tends to lower the temperature of the air below the dew-point is a cause of rain. It is, therefore, to the winds we must chiefly look for an explanation of the rainfall and the principles of this connection are these five (5) as given by Professor Stewart:

(1) When the winds have previously traversed a large extent of ocean, the rainfall is moderately large.

(2) If the winds at the same time advance into colder regions, the rainfall is largely increased because the temperature is sooner reduced below the point of saturation.

(3) If the winds though arriving from the ocean have not traversed a considerable extent of it, the rainfall is not large.

(4) If the winds even though having traversed a large extent of ocean, yet on arriving at the land proceed into lower latitudes or regions markedly warmer, the rainfall is small.

(5) If a range of mountains lies across the onward path of the winds, the rainfall is largely increased on the side facing the winds and reduced over the region on the other side of the range, because the air on the windward side is suddenly raised to a greater height by crossing the range, the temperature is further reduced by mere expansion and a more copious precipitation is the result. On the other side, the air descends to lower levels, because gradually dryer, and the rainfall diminishes with the descent.

In this latitude where the rainfall is distributed through all the months of the year and where snow covers the ground for only a small part of the year, the mean temperature of the soil equals that of the air.

Rainfalls naturally vary in accordance with the latitude. In lower latitudes the heaviest single showers ever recorded are:

Joyeuse, France, 31.17 inches in 22 hours.

Gibraltar, 33.00 inches in 26 hours.

Around Bombay, 24.00 inches in 12 hours.

Khasi hills, India, 30.00 inches in 24 hours, and record repeated for five days consecutively.

This somewhat explains how annual records in India reach 247 inches. In the United States and Canada to East of longitude 100 degrees West, the feature of the rainfall is the comparative equableness of its distribution, annual rainfalls exceeding 50 inches being restricted to very few districts, and rainfalls below 20 inches being very scarcely met with. The regions where rainfall exceeds 50 inches being Florida, the lower basin of the Mississippi, the Atlantic coast.

The summer winds of the southeastern coasts are southerly, and as they are anti-cyclonic in their origin and have in their course traversed some extent of ocean, they arrive well, but not supersaturated and pour down a heavy rainfall along the coast and for some distance inland from Louisiana to West Virginia. In June and July the southeastern winds attain their maximum force and persistency, and the rainfall at the same time reaches its maximum.

Observations have established a diurnal curve of rainfall, showing the minimum to be between 6 and 10 A.M. and the maximum between 2 and 6 P.M., these agreeing with the phases of the barometric pressure: the maximum period being near the time of minimum pressure.

Rainfall as we perceive it when it reaches the earth's surface is formed of rain drops varying in size from $^1/_{50}$ to $^1/_{10}$ of an inch in diameter in accordance with the intensity of the storm. In mists and fine winter rains the drops vary from $^1/_{50}$ to $^1/_{20}$ and in heavy summer showers average about $^1/_{10}$ of an inch in diameter.

Of all the species of water, that precipitated in the form of rainfall is the purest, but it is susceptible of offering the greatest variations. No water which occurs in nature is pure in the strict chemical sense of the term. Experiments related by Prof. W. R. Nichols of the examination of 73 samples of rain water collected on a farm in the open country, in England, demonstrate positively that rain water, however free from suspended particles of foreign matter which are visible to the eye, invariably contains in solution more or less of substances which in their ordinary condition are solids or gases. The rain which falls, even in the open country, is far from being chemically pure. The dust which floats in the air

often contains minute organized bodies—some rod-like, others globular—which prove to be capable of self propagation and which are endowed with motion, at least under certain conditions. These naturally occur in rain water, particularly in that which falls in the beginning of a shower, the water being purer naturally as the rainfall progresses, and its purity is proportionate to the severity of the storm.

Centuries ago, when sciences were less cultivated than they are to-day, and several extraordinary rainfalls were recorded, we are told of rains of sulphur, of sand, of cinders, of grasshoppers, of frogs, of blood, of stone, etc., all of which are easily explained by the various colored dust or the insects whirled through the atmosphere by the very swift storm that caused the rain.

The method of recording our local rainfalls is far ahead of the old system of open basins, and improvement in that is keeping pace with that of other branches of science.

To secure accurate information regarding rainfalls, I think the system at present being operated by the Drainage Commission to be very near perfect. Six self-registering rain gauges, distributed intelligently over the territory where the observation is desired, are kept in continuous operation under the care of reliable observers, and the daily records, automatically registered, are carefully filed at the central office. This, to an interested student, affords the best opportunity for investigation and comparison, showing conclusively that when accurate observations are required, one gauge, centrally located, will not give correct results for a large extent of territory. Thus we see, not at one, but very nearly at all times of the year, an excessive rainfall recorded at one gauge and no rain at another; or, again, a wonderful difference in the intensity and duration of the same storm at gauges comparatively close to each other. (See table "A.")

Another feature of importance in establishing stations for observing and measuring rain storms should be uniformity in the elevation of the several gauges. This feature I do not think was considered owing to the flatness of this territory. However, when one considers that a rain drop increases in size while it is being precipitated by absorbing the humidity of the atmosphere through which it descends, one must conclude that a difference in the elevation of the recording instruments, however small, must necessarily cause a relative increase in the amount recorded. For the purpose of comparison and to prove the theory, I have prepared table "A", exhibited herewith, and transcribed thereon a storm for each quar-

TABLE A. RAINFALL AT NEW ORLEANS, LA.

| | Elevation of Gauges Above | | STORMS OF UNIFORM INTENSITY. | | | | | | | | EXCESSIVE STORMS. | | | Example of Heavy Shower. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nat'l Surface. | Mean Gulf Level. | November 14, 1901. | February 23, 1901. | March 7, 1900. | February 22, 1901. | March 24, 1900. | February 25, 1901. | February 10, 1900. | April 12, 1901. | April 22, 1900. | April 17, 1900. | May 24, 1895. | May 31, 1901. |
| | Feet. | Feet. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| Dublin Gauge..... | 8.2 | 11 | .03 | .27 | .61 | .89 | 1.14 | 1.34 | 1.75 | 2.43 | 4.70 | 4.98 | 5.02 | 2.50 |
| London " ..... | 10.8 | 13 | .02 | .29 | .63 | .97 | 1.13 | 1.46 | 1.98 | 2.00 | 3.78 | 4.93 | 4.91 | 3.97 |
| Park " ..... | 3.9 | 14 | .00 | .27 | .46 | .90 | 1.13 | 1.30 | 1.72 | 1.94 | 4.83 | 4.39 | 6.03 | .85 |
| Algiers " ..... | 19.9 | 25 | .01 | .28 | .46 | .93 | .87 | 1.36 | 1.58 | 1.94 | 3.58 | 5.26 | 4.62 | .59 |
| Jefferson " ..... | 20.7 | 26 | .03 | .28 | .37 | .92 | .97 | 1.35 | 1.67 | 1.97 | 3.44 | 4.63 | 5.44 | .36 |
| Hall " ..... | 77.1 | 82 | .01 | .19 | .35 | .76 | .79 | 1.22 | 1.49 | 1.73 | 3.44 | 4.23 | 5.18 | .55 |
| Average ............ | ...... | 29 | .02 | .26 | .48 | .90 | 1.00 | 1.34 | 1.70 | 2.00 | 3 96 | 4.74 | 5.20 | 1.47 |
| U. S. Gauge ...... | 78.1 | 87 | .00 | .26 | .30 | .71 | .95 | 1.25 | 1.40 | 1.87 | 3.41 | 3.93 | 4.56 | .76 |

ter of an inch up to 2 inches. I have, of course, selected my illustrations, but only for the purpose of obtaining storms which seemed to be of uniform intensity over the entire district. Thereon I have established the elevation of the several gauges at present in use in this city, and for purposes of comparison have fixed their elevation to the nearest foot above mean gulf level.

It is fair to assume, owing to the small difference in elevation, that the Weather Bureau gauge and the Hall gauge are practically in the same horizontal plane, while the Park, Dublin and London are the lowest and can be used together, and the Jefferson and Algiers gauges are of the medium elevation. This affords an opportunity for a study of the records of the high, low and medium gauges.

It is certain, however, that although there is a very small difference in elevation between the Custom House and City Hall gauges and the territory observed is practically the same, the centres being only 2000 feet distant, there is a constant increase in the amount recorded at the low gauge. Table "A" clearly shows this. Besides, is it not evident that the six (6) gauges of the Commission, one of which (the Hall gauge) is on a level practically with the U. S. gauge, are giving a fuller record. It is undeniable that the lower gauges will uniformly give the larger record, however small and appreciable the difference in elevation.

This proves the assertion that to obtain similar results, even when the gauges are near each other, it is absolutely essential that they be in the same horizontal plane. As I have said I have, of course, selected the storms recorded, but I have done so only for the purpose of showing one storm for each quarter of an inch from a very light shower to a very heavy storm. I could have multiplied the examples citied, but assert after a careful perusal of the general records that these peculiar features are repeated for at least seventy per cent. of the storms.

Take any particular storm and compare the elevation of the gauges and the amount of precipitation recorded (see table "A"). You will observe from the map exhibited herewith, showing the location of the gauges referred to, that the distance between them varies from 5000 to 15,000 feet, or say a mean of 10,000 feet. An inspection of the record sheets for the several storms leads me to conclude that, for an accurate record of rainfalls over any territory, no gauge should be expected to serve for a district exceeding a superficial area of more than three (3) square miles, or a gauge, to be considered reliable in its record, should occupy the centre of a circle with a radius of not more than one mile or 5280 feet.

## TABLE B.

### Rainfall at New Orleans, La.

Showing date and total precipitation of storms which have occurred in New Orleans, from 1871 to April, 1894, where the total precipitation was in excess of 2.5 inches in twenty-four hours, gauged by the New Orleans Station of the United States Department of Agriculture—Weather Bureau.

| | Inches. |
|---|---|
| 1871—October 2, 3 | 2.95 |
| “ 30 | 3.04 |
| November 12, 13 | 2.80 |
| 1872—March 24, 25 | 4.50 |
| November 7, 8 | 4.48 |
| December 18 | 2.54 |
| 1873—May 5, 6 | 3.98 |
| “ 20 | 3.29 |
| August 20, 21 | 4.08 |
| November 4, 5 | 2.61 |
| 1874—April 16 | 3.84 |
| July 3, 4 | 7.52 |
| 1875—February 19 | 3.71 |
| March 11, 12 | 2.75 |
| “ 28, 30 | 3.81 |
| April 20, 21 | 2.90 |
| August 11, 12 | 2.77 |
| September 25 | 5.28 |
| December 4 | 3.82 |
| 1876—March 19 | 3.98 |
| “ 27 | 3.72 |
| April 7 | 5.51 |
| May 7, 8 | 4.09 |
| November 2 | 2.61 |
| December 31 | 2.59 |
| 1877—March 1 | 5.02 |
| September 17, 18 | 7.22 |
| October 24, 25 | 2.54 |
| “ 29, 30 | 3.52 |
| 1878—March 9 | 2.73 |
| May 19 | 3.54 |
| July 21 | 2.74 |
| 1879—April 16 | 2.82 |
| August 13, 14 | 2.60 |
| 1880—March 8, 9 | 3.36 |
| 1881—January 3 | 2.82 |
| July 3 | 3.25 |
| November 6 | 2.99 |
| December 13, 14 | 2.32 |
| 1882— | None |
| 1883—January 18, 19 | 3.71 |
| March 24 | 2.60 |
| April 7, 8 | 9.22 |
| June 8, 9 | 2.68 |
| 1884—April 4, 5 | 2.96 |
| 1885—January 4, 5 | 2.62 |
| September 20 | 2.78 |
| “ 25, 26 | 3.23 |
| December 12, 13 | 3.40 |
| 1886—January 14, 15 | 4.47 |
| April 27, 28 | 2.67 |
| 1887—June 29 | 5.47 |
| September 26, 27 | 2.88 |
| October 18, 19 | 3.19 |
| 1888—February 20, 21 | 2.72 |
| “ 23, 24 | 4.21 |
| June 6 | 2.86 |
| “ 26 | 4.44 |
| August 14, 15 | 3.70 |
| “ 19, 20 | 8.90 |
| “ 24, 25 | 2.80 |
| October 22, 23 | 4.13 |
| 1889—June 26 | 2.86 |
| “ 30 | 2.76 |
| 1890—June 22, 23 | 3.08 |
| October 15, 16 | 2.63 |
| 1891—February 14, 15 | 2.60 |
| December 14, 15 | 2.92 |
| 1892—January 10, 11 | 2.85 |
| April 21, 22 | 7.49 |
| August 15, 16 | 3.85 |
| 1893—February 11, 12 | 2.72 |
| April 19 (8 hrs. 40 min.) | 2.88 |
| June 5, 6 | 3.02 |
| October 1, 2 | 2.75 |
| November 26, 27 (9 hrs. 30 min.) | 3.35 |
| 1894—February 20, 21 (24 hrs.) | 3.59 |
| August 13 | 3.07 |

RECORD OF DRAINAGE COMMISSION.

| | |
|---|---|
| 1895—January 7 | 3.85 |
| May 24 (3 hrs.) | 5.20 |
| August 16 | 2.65 |
| 1896—June 23 | 2.50 |
| September 2 | 3.39 |
| October 27 | 3.13 |
| 1897—March 31 | 2.62 |
| 1898—February 17 | 2.86 |
| September 12 | 2.55 |
| “ 11 | 2.60 |
| “ 10 | 2.76 |
| 1899—July 25 | 2.80 |
| 1900—January 10 | 3.10 |
| April 22 | 3.96 |
| “ 17 | 4.74 |
| December 28 | 2.86 |
| 1901—April 17 | 4.27 |
| December 28 | 2.50 |

The table prepared by the Weather Bureau and published as Appendix, Report of 1895, Drainage of New Orleans, giving date of storms in excess of 2.5 inches up to April, 1894, has been extended to January 1, 1902, by adding the records of such storms from the Commission's records. (See Table "B"). I have endeavored to establish a percentage of the storms of different intensities as compared with the total storms for each year, with the following results:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rainfall | from | .01 | to | .25 | inches | = | 56 | per | cent. |
| " | " | .26 | " | .50 | " | = | 12 | " | " |
| " | " | .51 | " | .75 | " | = | 8 | " | " |
| " | " | .76 | " | 1.00 | " | = | 9 | " | " |
| " | " | 1.01 | " | 1.50 | " | = | 9 | " | " |
| " | " | 1.51 | " | 2.00 | " | = | 4 | " | " |
| " | over | | | 2.00 | " | = | 2 | " | " |
| | | | | | | | 100 | " | " |

The number of days on which precipitation is recorded average annually 118.

It is to be noticed that rainfalls in excess of $1\frac{1}{2}$ inches are quite unusual and that 2 inches or more are recorded very seldom, indeed.

Another very important feature is the average rate of precipitation and the average duration of the maximum rate.

The rate of precipitation is in many instances very great in comparison to the total rainfall—a rate of 2.5 inches per hour being quite frequent with a total rainfall of 0.5 inches or less. The greatest rate of precipitation which has been recorded is 7.2 inches per hour, or .12 inches in ten minutes, on July 4, 1894, and I find no longer record of any storm with such a maximum rate lasting over ten minutes, five minutes being the average duration of the maximum rate.

I submit table "C" a monthly record of annual rainfalls as recorded by the United States Weather Bureau at gauge marked U. S. on map, and by the Commission at the six (6) other gauges, together with an average for thirty-one, eight and eight years respectively, and have illustrated the figures in this table by the annexed diagram.

Now, as an illustration of our daily record and as our annual rainfalls from the Commission's records average 53.13 inches, I have plotted the daily record of 1901, as it is very nearly equal to the normal average.

The totals will suffice to illustrate what has struck me:

## TABLE C.

### Rainfall at New Orleans, La.

| Recorded by | Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U. S. Weather Bureau. | 1871 | 6.75 | 1.59 | 4.47 | 2.29 | 5.08 | 8.61 | 4.34 | 7.21 | 6.59 | 9.09 | 7.14 | 1.46 | 64.62 |
| | 1872 | 5.10 | 4.77 | 9.18 | 5.01 | 3.14 | 5.34 | 6.43 | 3.75 | 2.10 | 3.18 | 7.43 | 5.25 | 60.68 |
| | 1873 | 5.06 | 1.93 | 5.10 | 1.74 | 18.68 | 6.68 | 5.22 | 8.30 | 3.21 | 1.89 | 5.95 | 1.79 | 65.55 |
| | 1874 | 1.68 | 3.68 | 5.37 | 13.62 | 0.22 | 9.62 | 12.93 | 4.82 | 4.21 | 0.00 | 1.12 | 3.27 | 62.74 |
| | 1875 | 8.44 | 13.85 | 10.84 | 8.05 | 2.53 | 4.92 | 6.57 | 8 61 | 7.89 | 2.09 | 6.79 | 5.15 | 85.73 |
| | 1876 | 4.43 | 8.20 | 11.32 | 6.41 | 7.10 | 6.20 | 4.73 | 4.44 | 0.26 | 0.24 | 4.35 | 9.57 | 67.25 |
| | 1877 | 5.50 | 0 98 | 4.94 | 4.79 | 1.48 | 2.75 | 6.41 | 2.54 | 13 21 | 9.15 | 6.58 | 4.96 | 63.09 |
| | 1878 | 5.36 | 3.50 | 4.63 | 1.51 | 8.11 | 7.35 | 6.21 | 5.31 | 2.64 | 5.07 | 7.78 | 8.69 | 66.16 |
| | 1879 | 2.34 | 2.13 | 1.36 | 9.17 | 4.63 | 2.96 | 7.04 | 10.44 | 3.15 | 1.36 | 3.79 | 2.90 | 51.27 |
| | 1880 | 1.02 | 4.62 | 6.66 | 6.88 | 6.58 | 6.43 | 11.22 | 4.60 | 7.48 | 1.88 | 6.04 | 6.45 | 69.80 |
| | 1881 | 11.15 | 5.80 | 2.75 | 3.92 | 3.20 | 2.84 | 6.97 | 4.21 | 4.47 | 4.84 | 7.24 | 6.62 | 64.01 |
| | 1882 | 4.54 | 4.04 | 0.92 | 4.83 | 6.83 | 2.71 | 6.84 | 9.47 | 1.59 | 2 16 | 1.98 | 4.27 | 50.18 |
| | 1883 | 10.63 | 1.59 | 5.01 | 14.20 | 5.41 | 12.05 | 3.33 | 4.12 | 0 25 | 3.43 | 6.36 | 3 47 | 69.85 |
| | 1884 | 4.35 | 3.16 | 8.24 | 6.48 | 4.33 | 8.60 | 4.12 | 0.87 | 3.12 | 5.60 | 3.13 | 8.01 | 60.01 |
| | 1885 | 9.70 | 2.39 | 6.99 | 3.67 | 5.77 | 3.30 | 6.15 | 4.25 | 13.55 | 0.56 | 3.47 | 4.38 | 64.18 |
| | 1886 | 7.53 | 1.96 | 8.41 | 5.60 | 3.07 | 9.30 | 4.35 | 2.40 | 4.09 | 0.22 | 5.33 | 2.57 | 54.83 |
| | 1887 | 4.26 | 5.58 | 3.37 | 1.87 | 3 99 | 11.33 | 7.85 | 7.42 | 6.51 | 4.71 | 0.52 | 7.56 | 64.97 |
| | 1888 | 3.29 | 11.21 | 6.45 | 1.89 | 9.75 | 9.09 | 2.02 | 22.74 | 4.15 | 7.36 | 1.50 | 3.68 | 83.13 |
| | 1889 | 6.51 | 2.78 | 3.86 | 2.28 | 1.17 | 7.62 | 9.13 | 5.59 | 6.40 | 0.26 | 2.18 | 0.67 | 48.45 |
| | 1890 | 0.66 | 2.27 | 1.45 | 3.46 | 5.32 | 7.71 | 6.59 | 3.62 | 2.85 | 5.24 | 0.42 | 2.58 | 42.17 |
| | 1891 | 3.75 | 7.42 | 2.67 | 0.26 | 0.76 | 4.45 | 4.57 | 1.69 | 3.43 | 2.38 | 3.31 | 3.93 | 38.62 |
| | 1892 | 5.87 | 0.04 | 2.82 | 10.44 | 2.62 | 5.46 | 7.46 | 6.96 | 6.33 | 2.14 | 3.55 | 3.22 | 56.91 |
| | 1893 | 2.50 | 4.92 | 3.49 | 3.70 | 2.66 | 5.30 | 3.72 | 4.56 | 4.38 | 4.24 | 6.24 | 2.31 | 48.02 |
| | 1894 | 1.76 | 11.06 | 5.94 | 4.71 | 1.79 | 5.19 | 11.51 | 7.32 | 0.92 | 0.89 | 1.34 | 2.01 | 54.44 |
| | 1895 | 7.19 | 3.92 | 3.81 | 2.58 | 7.95 | 9.74 | 6.07 | 6.79 | 1.97 | 1.21 | 0.69 | 4.52 | 56.44 |
| | 1896 | 2.33 | 2.78 | 5.29 | 4.84 | 2.80 | 8.23 | 2.92 | 3.31 | 5.26 | 5.33 | 2.82 | 3.77 | 49.68 |
| | 1897 | 1.92 | 4.82 | 4.82 | 5.75 | 0.25 | 4.82 | 4.70 | 3.12 | 3.19 | 2.70 | 3.38 | 4.00 | 43.47 |
| | 1898 | 1.71 | 6.20 | 0.80 | 2.80 | 0.02 | 3.79 | 4.57 | 6.24 | 13.90 | 1.77 | 5.17 | 2.03 | 49.00 |
| | 1899 | 2.44 | 2.93 | 2.71 | 1.56 | 0 14 | 7.80 | 5.45 | 2.31 | 0.35 | 0.89 | 1.70 | 2.79 | 31.07 |
| | 1900 | 3.69 | 5.46 | 4.00 | 10.69 | 2.91 | 5.10 | 6.08 | 4.19 | 3.76 | 3.55 | 1.29 | 5.61 | 56.33 |
| | 1901 | 4.24 | 5.78 | 4.26 | 7.79 | 1.08 | 4.46 | 10.71 | 5.80 | 3.30 | 2.67 | 2.78 | 4.86 | 57.53 |
| Av. for 31 yrs. | | 4.69 | 4.56 | 4.21 | 5.25 | 4.17 | 6.44 | 6.33 | 5.69 | 4.91 | 3.10 | 3.91 | 4.28 | 57.54 |
| Av. for 8 yrs., '94 to '01. | | 3.16 | 5.36 | 3.95 | 5.09 | 2.12 | 6.14 | 6.50 | 4.88 | 4.08 | 2.38 | 2.40 | 3.57 | 49.63 |
| Drainage Commission of N. O. | 1894 | 2.11 | 13.27 | 1.74 | 4.35 | 2.50 | 4.06 | 8.19 | 7.58 | 1.37 | 0.75 | 1.15 | 1.94 | 49.01 |
| | 1895 | 7.62 | 4.48 | 3.69 | 2.46 | 10.33 | 10.47 | 6.87 | 7.38 | 2.10 | 1.35 | 0.79 | 4 86 | 62.40 |
| | 1896 | 2.50 | 3.08 | 5.22 | 3.24 | 3.16 | 9.56 | 3.59 | 3.85 | 5.88 | 6.62 | 3.68 | 3.62 | 54.00 |
| | 1897 | 2.08 | 5.22 | 5.32 | 5.48 | 0.48 | 6.31 | 5.06 | 3.47 | 3.94 | 3.76 | 3.13 | 5.15 | 49.40 |
| | 1898 | 2.00 | 7.36 | 1.14 | 3.25 | 0.12 | 3.41 | 5.62 | 5.50 | 16.02 | 1.54 | 6.29 | 3.13 | 55.38 |
| | 1899 | 2.55 | 3.35 | 2.90 | 1.83 | 0.12 | 9.57 | 5.88 | 3.05 | 0.35 | 1.70 | 1.94 | 3.40 | 36.64 |
| | 1900 | 3.88 | 5.98 | 4.49 | 12.27 | 3.36 | 6.77 | 8.43 | 4.97 | 3.63 | 2.52 | 1.26 | 6.45 | 64.01 |
| | 1901 | 3.34 | 5.74 | 3.80 | 7.74 | 1.79 | 3.56 | 9.61 | 5.00 | 3.22 | 3.25 | 2.53 | 4.40 | 53.98 |
| Av. for 8 yrs., '94 to '01. | | 3.26 | 6.04 | 3.54 | 5.08 | 2.74 | 6.71 | 6.66 | 5.10 | 4.56 | 2.72 | 2.60 | 4.12 | 53.13 |

The most surprising feature of the table, when a comparison is made of the averages of the records of the Weather Bureau, respectively for thirty-one years (1871 to 1901- and eight years (1894 to 1901) and those of the Drainage Commission (1894 to 1901), is the steady decrease in the total recorded by the former and the steady excess of the Commission's record over those of the Weather Bureau. What is the cause of this steady deficiency? The improved instruments for recording rain storms are a comparatively recent invention, and no doubt the records obtained thirty years ago were somewhat imaginary and not so thoroughly accurate. But, then, how can we explain the extraordinary downpour of 1888 (August 18th-19th)? Is it because the atmospheric conditions of our climate are steadily changing? Is our Southern territory becoming colder? These are questions which I acknowledge are submitted with the hope that someone will answer them. I do not pretend to be able to explain them even after the careful study of the general principles governing the laws of atmospheric changes recited at the beginning of this paper.

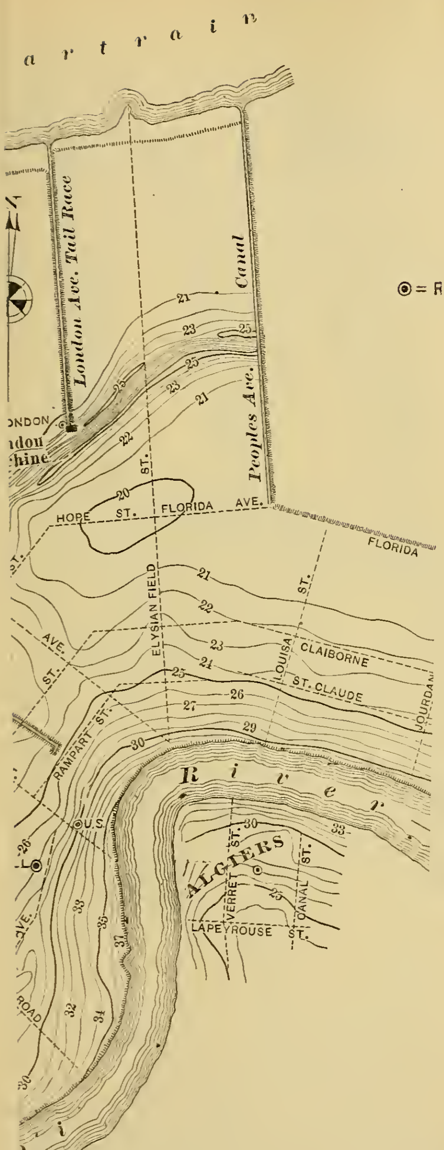
Mr. I. M. Cline, our very efficient local official, in an interesting paper on the precipitation and flow of rivers in Texas, says:

"Some investigators claim to have found periodicity in precipitation. Professor Bruckner, of Berne (Klimaschwankungen, Vienna, 1891), has deduced from observations at 321 points scattered over the earth's surface, from the longest records available that there are thirty-year periods of rainfall; that is, from a maximum it decreases for fifteen years to a minimum, then increases for fifteen years to a maximum again, and so on, giving thirty years from a maximum to another, and thirty years from a minimum to another. Professor Bruckner's figures after being smoothed out, place one of the periods of minimum precipitation about the present time (1895). There are, however, irregular variations from time to time, which cover up for the time of these fluctuations, but in the main there is strong evidence that such periodicity exists.

"This is a very important question and the records which are now being kept by the United States Weather Bureau will, in due time, serve to demonstrate the truth regarding such periods as they may apply to this country."

Now, let us examine table "C" herewith submitted. Assuming the highest record (1875) to have been at or very near the maximum period, then the minimum period would be about 1890. It is, indeed, remarkable to note that the total next following (1891) is very near the lowest on record, and this after almost a constant

ALFRED F. THÉA




CONTOUR MAP

Scale of Feet

0 1000 2000 3000 4000 5000 6000

Scale of Metres

0 500 1000 2000

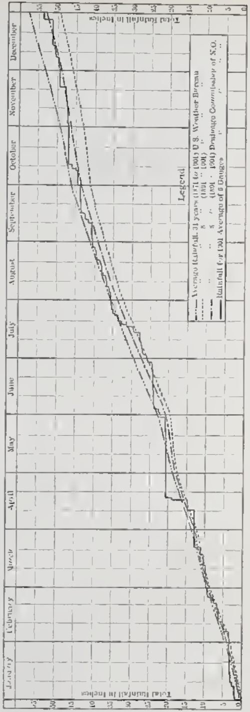
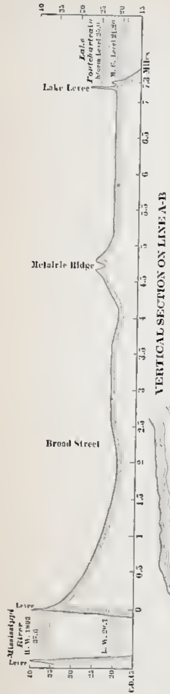
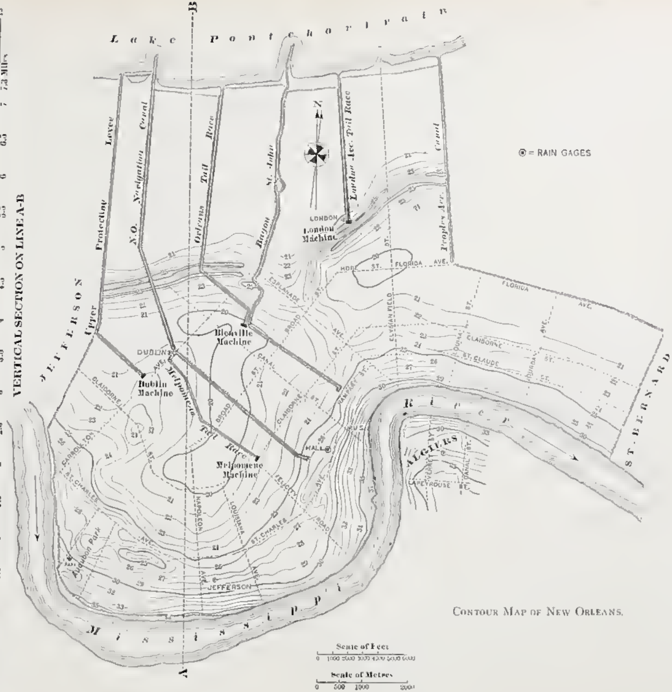



Diagram of Rainfalls




VERTICAL SECTION ON LINE A-B




Contour Map of New Orleans.

decrease (from 85.73 to 38.62) and that with little exception the record again increases steadily from 1891 to date. This undoubtedly supports this theory, and we should therefore look for another maximum about the year 1905 or 1906.

But, after all, what is an inch?—a small insignificant inch of rainfall? Very few people realize what it means, and you will pardon me if I cite here a few illustrations. For a city, with a superficial area of say 25,000 acres like New Orleans, one inch of rainfall means very nearly 680,625,000 gallons of water; and, again, assuming the population to be 300,000, living in 60,000 houses, that the roofs of these houses average 1200 square feet each, then the total amount of rain water collected in the cisterns when a one-inch rainfall is recorded is 6,000,000 cubic feet, or very nearly 45,000,000 gallons. Further, 50 inches is a reasonable assumption for our average annual rainfalls; allowing that no water is wasted by the overflow of cisterns in excessive storms, or other causes, then our annual rainfall would yield about 7500 gallons per capita per year, or 20½ gallons per capita per day.

This is, as you see, only a small part of the total amount precipitated on the superficial area of our city, and what proportion of this and of the balance is to be taken care of by our drainage system could form the subject of an interesting paper.

I had intended here to go into the study of run-off, but the question is too important for such hasty consideration as I could give it in the remainder of this paper.

In closing, I desire to say that, when I undertook to prepare a paper on "Rainfalls," I had not fully realized the magnitude of the task, and a close study convinced me that I could not do full justice to it in one paper without imposing on the good nature of my audience.

Have I said enough? I leave you to judge, but I can assure you that the amount of study necessary for the preparation of this paper has been of invaluable benefit to me, and that, as I got more and more interested, I spent many an evening up in the clouds.

In this paper I have often quoted Mr. A. Buchan, Professor Balfour Stewart, Encyclopœdia Britannica, Encyclopedie Moderne, Prof. Wm. P. Nichols, and Report on Drainage of New Orleans. All the records of the United States Weather Bureau which were cited were obtained through the courtesy of our able local forecast official, Mr. Isaac M. Cline, and his assistant, Mr. Alciatore.

# THE REAL NATURE OF ELECTRICITY AND MAGNETISM.

By Arthur A. Skeels, Member Civil Engineers' Club of Cleveland.

[Read before the Club, May 13, 1902.*]

In a paper read before this Club in February, 1901, and published in the Journal of the Association of Engineering Societies in March, 1901, we explained briefly the evidence which goes to show that in the same way that molecules are groups of atoms, so are the atoms groups of smaller parts which we may call subatoms, that the subatoms are groups of still smaller parts which we may call sub-subatoms, these sub-subatoms groups of still more minute parts, etc., down to an ultimate atom which cannot be further divided.

That in the same way that there are gases made up of groups of atoms (molecules), so are there subgases made up of groups of subatoms and sub-subgases or ethers made up of groups of sub-subatoms, etc.

Furthermore, there may be as many kinds of subgases and ethers as there are kinds of ordinary gases; but for the present we will consider that as there is one general atmosphere—air—of nearly constant composition, so is there one general subgas and one general ether of nearly constant compositions.

We will carry the analogy still further and state that as there are disturbances in the air, winds, cyclones, waves, condensations, rarefactions, etc., so are there similar disturbances and motions in the subgas and ether known to us as light, heat, electricity, magnetism, etc.

This subject is too large to be treated in a complete manner in a paper of this kind. Time and space will not permit here a discussion of all points nor the giving of all reasons and arguments. We will, therefore confine ourselves principally to results and conclusions, and, for the sake of clearness, take up special illustrations instead of generalities. If my paper seems rather disconnected it is due to a desire to cut it down to a reasonable length.

We have reason to believe that, at least as far as our observation from the earth is concerned, the ether extends throughout all space; but the subgas is not so plentiful and only exists, on the earth at least, as condensed within and very near the surface of atoms, molecules and bodies. The particles making up the sub-

*Manuscript received May 17, 1902.—Secretary, Ass'n of Eng. Socs.

gas are so small that they circulate among and between the atoms and molecules of ordinary bodies as air molecules will circulate among and between the stone in a stone heap, while the particles making up the ether are so small that they circulate between and among the subatoms and the particles of the subgas. Of course, there is resistance to this circulation just as there is resistance to the circulation of air between and among the stones.

I would say here by way of parenthesis that the evidence of the existence of this subgas, a substance which holds a place between the ordinary gases and the ether, was discovered by investigations of the physical and chemical properties of matter. Some time afterward a study of the phenomena of electricity and magnetism caused me to believe that they could not be motions in the same medium. Further investigation led me to believe magnetism to be a motion in the ether and electricity a motion in the subgas.

We will now try to show what are the functions of the subgas and ether in electricity and magnetism.

Fig. 1.

Let Fig. 1 represent a portion of a copper wire. All through this wire and extending out from its surface for an extremely short distance is the condensed subgas, while all through the wire and all about it extending indefinitely in all directions is the ether.

The condensed subgas acts like a shaft supported by the wire; if this shaft suffers a torque, this torque is transmitted along this shaft and power is conveyed somewhat analogous to the way power is transmitted along a steel shaft in a machine shop.

When an electric current is passing along the wire it means that this subgas shaft is rotating and conveying power along the wire.

The particles of the wire naturally offer a resistance to the flow of the subgas during the rotation, and this resistance very naturally will vary with different materials and even in the same material will evidently vary with any change in that material, such as temperature, purity, density, etc.

The friction of the subgas in flowing through and around the material of the wire develops heat in the wire and, of course, the greater the current,—that is, the greater is the flow of the subgas the greater will be the heat developed. There is also friction

between this subgas and the ether about the wire,—that is, the rotation of the subgas shaft sets the ether about the wire rotating in the same direction, similar to the way that a shaft rotating in water will cause the water to rotate all about it, the rotation growing feebler as the distance increases and the greater the distance from the shaft the more does the rotation lag behind; or, in other words, the angular velocity of the rotation grows less as we go away from the rotating shaft.

That is, while the current itself is confined to the wire, or at least cannot get, in general, but an extremely short distance from it, the influence of the current in the ether extends indefinitely on all sides. Evidently the subgas shaft may rotate either to the right or the left around the wire. If we call one direction positive the other will be negative. Ordinarily, however, when we speak of the direction of a current along the wire, we refer to the direction in which the power is transmitted.

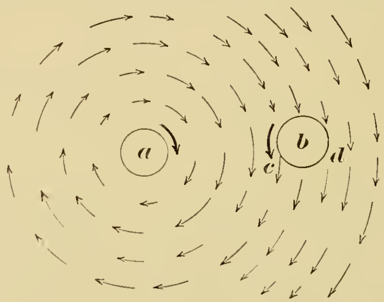



FIG. 2.

Suppose a current be sent through the wire a, Fig. 2, so the rotation is in the direction shown by the heavy arrow. The ether all about is rotated as shown by the light arrows. As this rotating ether spreads out from a it first strikes the near side of the wire b and sets up a rotation of the subgas shaft of b in the direction shown by the heavy arrow,—that is, in an opposite direction to that in a, thus producing an induced current in wire b in an opposite direction to the current in a. In a very short time the ether whirl passes on so as to strike the far side of b also and tends to turn the subgas shaft in the opposite direction and neutralize the first effect.

As long as the current, that is the rotation, in a is increasing, the ether whirls around a are increasing in intensity and the side c of the subgas shaft of b is under a greater stress than side d. The rotation in b continues. When the rotation in a

becomes constant, the ether whirls become constant, the sides c and d are under practically the same stress and practically neutralize each other. When the current in a slows down the side d is under greater stress than c and the whirl in b is in the opposite direction from that shown by the heavy arrow. Thus a current starting in a induces a current in b in one direction; in stopping it induces it in the opposite direction, while a constant current in a induces no current in b at all.

Evidently, the greater the rate of change of the rotation in a the greater is the difference in the stress between c and d and the greater will be the torque in b,—that is, the greater will be the induced current.

The electromotive force is the torque; the greater the torque tending to turn the shaft the greater, we say, is the electromotive force.

In Fig. 2, evidently, the nearer a is to b, and the more sudden the change of current in a and the greater distance a and b run parallel, the greater will be the torque or electromotive force of the induced current.

Anything which increases the spaces between the atoms and molecules will make resistance less by giving a freer passage to the flow of subgas. An exception to this would be when the spaces became so great as to break the continuity. On the other hand anything which increases the roughness of the atoms or molecules will increase the resistance to the flow of the subgas.

Heat, in general, will increase the spaces between the atoms and molecules and thus tend to decrease the resistance; but heat by causing the subatoms to vibrate will increase the roughness of the atoms and molecules and tend to increase the resistance. Hence, heat will increase or decrease the resistance of a substance according to which of these two effects predominates.

In the same way as in the case of a steel shaft the velocity of rotation depends upon the torque (electromotive force) and the resistance. With a given torque the less the resistance or friction the greater will be the velocity of rotation (current). The greater the velocity of rotation (current) and the greater the friction (resistance) the greater will be the heat developed, the same again as with an ordinary steel shaft.

It would seem that an alternating current in c, Fig. 3, or the making and breaking of a current in c might cause the subgas shaft in mn to rotate and so form a current without a circuit being necessary. This is, indeed, true; but, ordinarily, the induced current is too weak to be detected or else a series of torsional

waves is formed which, by reflection from m and n, pass back and forth with such rapidity that they practically neutralize each other. However, such currents were detected by Hertz where the inducing force was high-tension electricity of extreme rapidity. If, however, mn is bent around to form a circuit the induced current flows round and round, all the effects are added and the current becomes appreciable.

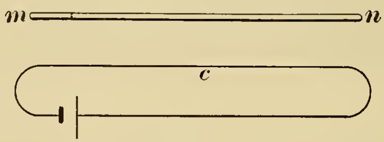



FIG. 3.

Inertia plays an important part in electric phenomena, when once in rotation the subgas tends to continue in rotation. It is this tendency to continue that causes the arc when a conductor is broken and adds to the effect of self-induction. It is due to inertia that currents of very high electromotive force when suddenly induced will pierce an insulator rather than go a longer way through a good conductor. It is more difficult to suddenly set the long subgas shaft of the conductor in rotation than it is to pierce the insulator, although the ordinary resistance of the conductor is but a very small fraction of that of the insulator. In starting an electric current as in starting a railway train we have two resistances, ordinary resistance, friction and a resistance due to inertia. The first is fairly constant; the second depends upon acceleration.

We have magnetic waves, such as those of wireless telegraphy, which travel through the ether and have the velocity of light. We also have electric waves which travel through the subgas along conductors and whose velocity is independent of that of light. Electric waves may be those of condensation and rarefaction, torsional or even transverse. Also, they may have different velocities of propagation.

Since the molecules and atoms of bodies are in ceaseless vibration they disturb the subgas. When two dissimilar substances are brought in contact the result of the vibrations of the dissimilar atoms and molecules is to cause rotations in the subgas upon the surfaces of the bodies; and, since action and reaction are equal and opposite, the rotations on one body are equal in force and opposite in direction to those on the other. When the surface of a body is covered with these rotations in the subgas, which are analogous to tornados in the air, it is said to be stati-

cally electrified. If the rotations are in one direction, the body is positively electrified; if in the other direction, the body is negatively electrified.

It may seem at first sight that it would be impossible for power to be conveyed by a whirling motion along a shaft of a gas-like substance, but we need only to consider the enormous power in the rapid whirling tornado, which is but a gas—air—to understand how such a thing is possible. Besides, a current of electricity represents but a comparatively little force, but this little force may convey an enormous power by reason of its extremely high velocity.

When a liquid or solid is changed to a gas or vapor the molecules and atoms also expand. This makes them rougher and they offer more resistance to the passage of the subgas; hence the gas or vapor has a higher resistance. In fact, the resistance becomes so great that when the subgas current flows the friction causes the gas molecules to be carried mechanically along, and since the velocity is so great the amount of energy required is very great. This causes so much disturbance that light and heat results,—that is, a spark.


Fig. 4.

When one conductor ab, statically electrified, is near another conductor cd, Fig. 4, the whirls in the subgas on ab set up corresponding whirls in the ether. The whirls in the ether extend out and cause corresponding whirls in the subgas of cd, thus electrifying it by induction. It has been found that the inductive effect of ab upon cd depends somewhat upon the nature of the insulating material between; those substances which offer the least resistance to the ether whirls will allow the greatest inductive effect. It is not surprising that equally good insulators do not form equally good dielectrics for one property refers to the resistance to the ether whirls, while the other refers to the resistance to the subgas whirls.

When a current passes through a liquid in electrolysis, the violent twist of the subgas over the rough molecules and atoms of this comparatively poor conductor causes the molecules to be torn to pieces.

In a manner similar to the way that objects are drawn or sucked up along the axis of a tornado, in air, so does this whirl in the subgas tend to draw the atoms along the axis and, as some objects by their shape, etc., are more easily drawn up by a tornado, so are some atoms more easily drawn along by the subgas whirls than others. Those atoms which are more easily carried along, due to shape, size, roughness, etc., are called more electro-positive than the others. But some atoms are left behind, else there would be formed a vacuum. Those left behind are attraced to the electrode and either cling there or escape, according to the amount of attraction. The more electro-positive atoms go on to unite with the others according to a theory of exchange of atoms long ago suggested.

The whirl or twist of the electric current tends to tear the molecules of a substance to pieces, hence the fatal effect of a current in the body when it has force enough to tear the molecules of tissues, etc., apart. On account of inertia time is required to tear molecules to pieces; hence, if before this time is sufficient, the current changes direction,—that is, the whirl starts in the opposite direction; the effect of the first twist is neutralized and, if the time is too short before the current or twist again changes, the third twist will neutralize the second, etc. Hence, a person can receive without harm a current of extreme high voltage if the alternations are extremely rapid.

In case of a simple cell the contact of the sulphuric acid and zinc causes different molecules to be brought together, the agitation of these different molecules and atoms, heightened by chemical action, sets up whirls in the subgas which, being carried away, are continually replaced by new ones, causing a constant current. If it were not for the chemical action the molecules and atoms in contact would soon by mutual action acquire the same motion and no longer disturb the subgas in a manner to produce these whirls. Without chemical action the current would last but a very short time. Chemical action keeps the different molecules and atoms in contact continually replaced by new ones, and, hence, they cannot acquire the same motion.

Investigation seems to show that when two dissimilar substances are electrified by being put in contact, the one whose molecules produce the greater disturbance in the subgas on its surface becomes positive. This means really nothing more than that the subgas rotation of any body is always in the same direction when it is in contact with a body of more sluggish molecular action. However, the mere velocity and amplitude of molecular

motion may not determine the amount of disturbance in the subgas. The shape of the molecules and atoms, and the interference of other foreign atoms, may materially affect the real disturbance of the subgas. When the junction of two dissimilar metals is heated, as in thermo-electricity, we get a continuous current because the heating continually changes the molecular motion of one faster than the other.

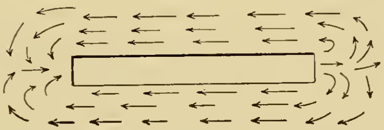


FIG. 5.

Let Fig. 5 represent a bar magnet. It is a magnet by virtue of a flow of ether which continually flows out of one end and returning outside enters again at the other end. The figure is a diagram and it is not intended to show the actual direction of the lines of force. This flow is kept up by the vibration of the atoms, or subatoms, or both. In the ordinary bar of unmagnetized steel the vibrations of these atoms or subatoms, acting in all directions, neutralize each others' effects and produce no noticeable current in the ether, but under the influence of a strong ether flow set up by another magnet or electric current, they are turned into a direction so as to act together. They will then continue to keep the ether current flowing as long as they vibrate together. The energy to keep the ether current flowing out and into the magnet is derived from the atoms or subatoms themselves, and they in turn derive their energy from outside sources,—radiation of other bodies, etc. This would seem to show a tendency to use up the atomic or subatomic motion in the magnet. This effect might not directly change the temperature of a magnet, for it is not a molecular energy which is used up. It would seem that if a magnet were cooled to a very low temperature the motion of the atoms and subatoms would grow less, because of fall of molecular energy, whose collisions help produce their vibrations, and, hence, the ether current would gradually lose its motion. This is actually found to be the case, for a steel magnet loses its magnetism at about—100°. On the other hand, a high temperature, by giving too great a vibration to the subatoms and atoms, would destroy the uniformity of the motion, cause them to vibrate in all directions and destroy the motion by interference as in an unmagnetized steel bar.

The formation of an induced current in a coil of wire by a magnet is similar to that already described by the action of one current upon another. Whenever a magnet moves near a wire so the ether motion produces a greater stress on one side of the subgas of the wire than the other, an induced current results. The whirl of ether about a live wire is such that a coil produces a flow of ether similar to a magnet; hence, the solenoid has the properties of a magnet.

When a steel bar is magnetized we force the atoms or subatoms to vibrate so as to act together in making the ether flow. The more perfectly we arrange these subatoms the more perfectly the bar is magnetized, but evidently when all the subatoms are thus arranged, to magnetize the bar further would be impossible. It has been found to be a curious fact that if a magnet armature be weighted with as great a weight as the magnet will support, and this weight left there for some time, then an extra weight may be added without pulling away the armature. After some further time still more weight may be added, and so on until by this process the magnet will support a much greater weight than it would if it were all put on at once. This may be explained by considering that under the extreme stress the subatoms of the magnet become gradually better arranged to keep up the ether flow and hence give stronger effect. If this explanation is the true one, it is evident that the phenomenon just described would not be shown by a magnet which had been magnetized to saturation.

It may seem strange that a to and fro vibration of the subatoms could give a current of ether flowing in a constant direction, but when we consider the enormous variety of shapes and motions which molecules, atoms and subatoms may have, it does not seem so unreasonable that in an occasional case this effect may be produced. It has been noticed that under certain conditions vibrating tuning forks will attract each other. This seems to be due to currents set up in a similar way to that just described in magnets.

The explanation why magnetic waves in the ether will reduce the resistance of contacts (coherers) in wireless telegraphy may be given thus: Let Fig. 6 represent three particles, greatly magnified, in close proximity, but having poor contact. The shaded portions about these particles represents the layer of subgas. Since a flow of ether will cause movement of subgas, when an ether wave comes along from aa in direction of the arrows, the flow of ether as it goes ahead to form a condensation in the wave

motion, strikes the subgas layers at cccc and crowds it in toward dd between the particles, thus making a better contact and reducing the resistance between the particles in the direction of EF. Attraction will tend to hold the heaped up subgas at dd, and often it does this unless a disturbance (mechanical or otherwise) causes the subgas to take up its former position of equilibrium.

As to the X rays more study and investigation is necessary to speak with any degree of certainty; but, if we consider the fact that denser bodies offer more resistance to these rays than lighter ones, that transparency to X rays is independent of transparency to light, and if we assume what is stated to be true that a flow of X rays makes a gas a conductor of electricity, it seems to me that it is quite probable that X rays is a wave motion in the subgas. Each molecule of air has about it a subgas atmosphere, but ordinarily the molecules are so far apart that these subgas atmospheres have a poor contact with each other. Any vibration

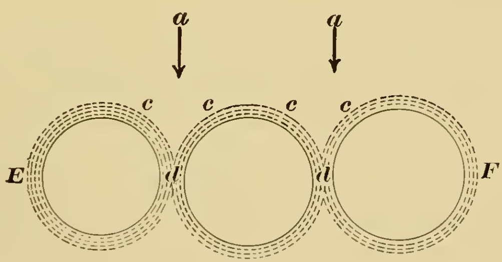



FIG. 6.

in the subgas with sufficient amplitude would surge across these spaces and thus overcome this lack of continuity, making the air a conductor. It seems to me that any agency which would produce vibrations in the subgas of sufficient amplitude would produce vibrations which would be propagated through the subgas of the air and we would have X rays. The difference between X rays, Becquerel rays, etc., may be simply one of amplitude, and the reason that actinium, radium, etc., will produce these rays may be nothing more than that these substances have sufficient molecular or atomic motion to produce the requisite amplitude.

My experiments have not yet been carried to a point where I wish to publish much about them, but I will mention one.

I caused a stream of sparks from a static electric machine to play over a silver half dollar fastened tightly upon a sensitive plate. When the plate was developed the raised portions of the

coin, the head, printing, etc., which had actually been in contact with the film, were photographed in black. The other parts of the film under the coin were unchanged. It is difficult to see how X rays or any other radiation, except they were in the subgas, could go so completely through the thicker parts of the silver and not at all through the thinner parts.

My explanation is that the extremely rapid discharges of the static electricity caused vibrations of the subgas in the coin of an amplitude sufficient to force the subgas out far enough from the silver to affect the film where it touched, but not far enough to cross the slight space where the metal did not touch the plate.

Since performing this I have read in an English paper of a similar experiment, where an induction coil was used instead of a static machine.

However, it is not to be expected that any one experiment can be conclusive, we must depend upon the collective evidence of a great number.

Heat is conducted through a body principally in two ways,— from molecule to molecule and by means of waves in the subgas, which are afterward absorbed by the molecules of the body. It is a form of radiant heat limited to the subgas. Other things being equal, the less resistance the material of the body offers to the motion of the subgas the more rapidly does the heat pass through the body. From the fact that the relative heat conductivity so nearly agrees with the relative electric conductivity seems to show that the subgas is the principal agent in the conduction of heat.

## DOCK CONSTRUCTION IN AND AROUND BUFFALO.

By S. M. Kielland, Member American Society Civil Engineers, Member Engineers' Society of Western New York.

[Read before the Society, April 1, 1902.*]

The subject of docks and wharves is a very timely subject for us engineers to consider. I did not intend to give my talk such a wide scope as our secretary claims it has; anyway, I have chosen this subject because our President has asked me to say something on it, not because I think I have any special knowledge to reveal, but I hope the discussion will bring out our ideas and help to formulate correct lines to follow when we are called to form plans by which our city and its people will get the best and most serviceable harbor. This question in all its bearings is about the most important concerning the future of Buffalo. Something more systematic ought to be done. A general plan should be developed and afterward the details would follow. This patchy, irregular, haphazard way in which this important question has been drifting is unworthy of a progressive, intelligent and well-informed population such as we boast of having. It is unworthy of us engineers.

In connection with this question comes, of course, that of raising the levels of Lake Erie by a dam, deepening the channel of Niagara River, etc. To me it looks as if a 3-foot rise of the water level is too much. A rise of 18 to 20 inches would be more nearly correct considering the many improvements which would be damaged and abandoned by the higher level. Otherwise 3 feet would be the best. It would be very easy to increase it later on to 3 feet if found desirable.

To come to the right conditions in all these improvements, to make the right designs, we have to know and understand the condition of those underwater foundations as well as those above, which comes from wind and weather and waves, as well as the usage to which our docks are going to be put.

Docks are defined by Webster as deep trenches on the side of a harbor or bank of river, where ships are built and repaired. We have dry docks, wet docks, also docks where ships are let in at high water; the entrance is closed, and they have to remain to the next high water to be let out. Here in America the spaces between wharves are also called docks.

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Quay-Ke'. If the same as Key, it is what fastens and secures a mole or bank formed toward the sea or on the side of a river for the purpose of loading and unloading ships (Quay-age, Ke'age); Wharfage; Wharf. It is about the same name in all northern languages. Webster calls it a perpendicular bank or mound of timber or stone or earth raised on the shore of a harbor, river or canal, or extending some way into the water for the convenience of loading and unloading vessels.

In the immediate future, and even now, many questions relating to harbor, docks and wharves are upon us. Ill-selected or well-selected designs mean a great deal to ourselves as well as to those whom we serve as engineers or agents.

The new breakwater is nearly finished; the outer harbor has many conditions different from the more sheltered river and city ship canal. I do not see the need or time or place to go into many construction details or to those relating to the strain, strength or load. These questions may be treated in each case as they come up.

The first questions which appear in construction of wharves or docks are their location, the purposes for which they will be used, if on the inner or outer harbor. From these come the questions of foundations. In a general way I think it is correct to state that rock foundation is to be had from the present harbor entrance of Buffalo River and northward along Erie Basin and down the river. In a great deal of this a portion of the rock has to be mined away so as to give sufficient depth to vessels; also, that a good pile foundation can be obtained south of the harbor entrance up along the river to near Erie Elevator and to south end of lot 2 on the Blackwell Canal. Piles will reach rock 30 to 45 feet in length below city water line. Above the Erie Elevator on the river all structures can be built direct on the rock; this as far as the present navigable portion is concerned.

Cribs, masonry and concrete here make the most suitable wharf frontage. When rock dips down to a greater depth on the river, good pile foundation can always be had.

Nearly all wharves or heavy structures which are going to be built east or south of the points mentioned will demand heavy, long piling. On the Tift farm soundings or borings were made, and rock was reached at a depth of 50 to 80 feet below the surface. I believe that up toward Stony Point the rock rises again a little, but a great portion of this land was covered with a thicker layer of muck and soft clay and, therefore, requires piling in proportion. On the Tift farm, as well as on the Blackwell or City Ship

Canal, there is found a stratum of harder material from 20 to 40 feet below water. It gives usually a good bearing for piles, yet, if the pile is driven hard, it will penetrate this layer and a softer material is entered.

On the Tift farm, where many thousands of piles are driven 60 to 70 feet deep, many were spliced. I feel confident that equally good results could have been reached by using shorter piles, either driven to the hard stratum or only 50 feet long. The suction or cohesion is here equal to a very good foundation for the point and much more economical.

The docks most common in Buffalo can be divided into the following kinds:

1. Excursion docks.
2. Lumber docks.
3. Docks for rails, stone and similar heavy stuff.
4. Ore docks.
5. Retaining docks.

All these docks ought to be designed according to the use they are going to have. A dock that is built for a certain purpose or a certain load should be proportioned for that purpose or load. If we put 500 pounds on our back to carry, most of us will sink down—our knees give away. So with a dock if loaded beyond its strength and foundation. Also, if you put too much money and material into a structure, it is equally bad practice.

It seems ridiculous what wise faces are put forth when these natural collapses occur. Instead of finding it perfectly correct, it is attributed to extraordinary reasons and mysterious causes—the construction was wrong, the foundation was not understood, the load was too heavy. It would take a large book to write only a small portion of what there is known related to wharves. It would also require many illustrations. I have not time or intentions to do anything here beyond giving a few suggestions.

An excursion dock is, as a rule, the lightest dock. It ought to be strong enough to stand a packed crowd of people with their luggage and bear the bumps of the steamers. It ought to be carefully constructed, elastic and well tied together; and there must be no chance for it to give away, as it has the most precious load—human life. There ought to be on these docks apparatus for saving life—ropes, boats, buoys, etc. There must be appliances to and from which boats can easily be secured and released. If the dock is built upon piles, those can be 10 to 12 feet apart, with split caps, 3 x 12-inch joists. It should have several continuous girths as fenders. The top planking ought to be well

tied down and the whole structure bound together with bolts and spikes.

Such excursion docks are, of course, of a temporary construction. When the city begins to build permanent docks along the river front, where rock foundation can be had, cribs with concrete or stone fronts above water are the thing to build.

### LUMBER DOCKS.

Of these we have many. They are usually made by pile bents, 8 to 12-foot centers and with two to three piles in a bent. The bents are often tied back to anchor piles at intervals of every other bent, usually sheet piling behind the dock. These docks must be strong enough to receive the lumber as unloaded from the ships, and they may at times have to sustain stacks of lumber 15 to 20 feet high, but, as these are soon removed and stacked or stored on adjacent land or in lumber yards, and, as timber is not high in specific gravity, the load, neither on the dock nor on the near land, comes very high per square foot. Besides, there are always left spaces between piles for driveways. These docks seldom have any accidents. They are built rough. There ought to be a sufficient number of snubbing piles. There is a great variety in lumber docks. Some are built with only two rows of piles, with sheet piling. Others, like those of the "Lehigh" built on the Tift farm, were about 42 feet wide, bents 12 feet apart, with 6 or 8-inch piles in a bent. I do not consider that these docks were economical. They cost about $25 to $28 per foot. They were first without sheet piling, but washing down and caving has necessitated this to be done later on.

### DOCK FOR SHIPMENT OF RAILS, STONE, ETC.

It gradually became necessary to have stronger docks than the lumber docks. Then docks with the bents only 6 to 8 feet apart, with piles in these only 3 to 4 feet between, were built. These wharves have to sustain loads of steel rails 8 to 10 feet high; sometimes, also, the cars from which they are unloaded. These docks ought to be wide and should be extra strong in all parts; the exposed parts to be oak timber, to stand the rough handling which naturally follows from these cargoes. The piles must be driven to good bearing, either to rock, if this is not too far down, or to the stratum of hardpan before mentioned, at a depth of from 30 to 45 feet. Once in awhile, when a sliding or breakdown occurs, we hear about a stratum of quicksand as being the cause. This is supposed to relieve the engineer or contractor. This providential quicksand has interfered with work

which I have had in charge myself. When the foundation pit for the railroad bridge at Hamburg Turnpike was sunk, we found in the pits, 18 to 20 feet down, several thin layers of sand in between the clays. They seemed to conduct water and might be the offending quicksand.

IRON ORE DOCKS.

These docks are somewhat new in this locality. They have to sustain an enormous load, and almost all the first docks have failed. They have caved in on the Tift farm, on the City Ship Canal and on the river. It looks as if a strong enough construction has now been found.

The iron ore dock on the Tift farm which gave away was one of the lumber docks described. Special foundations were made for the Brown hoist which handles the ore. The ore was piled close up to the back of the dock, when suddenly the ore heap, which was unloaded on planking laid on mud sills, sank down. The natural surface of the Tift farm had here been covered with a layer of clay 6 feet thick. The original ground consists of 2 to 3 feet of black muck and under this a foundation of glacial clay, rather plastic. This foundation gave away. The ore might have been unloaded to a height from 25 to 30 feet in big heaps as it sank down. The movement pulled the dock piles up, so the dock line for about 200 feet was not only pushed into the canal about 12 to 15 feet, but also elevated in a parabolic shape, with a maximum rise of about 12 to 15 feet. The ore as it sank pushed the clay up so that it formed a dam. No water came into the sinkhole or cavity, and the Brown hoist, when readjusted, took the sunken ore out of the cavity. After this the ore heaps were placed farther away from the front; besides, sheet piling was driven back of the dock. The general conclusion I have derived from these experiences in Buffalo is that iron ore can be unloaded with safety if there is plenty of margin between the wharf and the heaps and if the load can be placed far enough back. There ought to be a plank flooring to facilitate shoveling. If the space is narrow, there are two ways, either to strengthen the foundation with a pile-supported floor or else build an exceedingly heavy front, either by cribs or piles; but both have to be anchored very strongly to sheet piling or anchor piles. Cribs without these, standing on our slippery clay, are both sure to slide and to sink. If they are not sunk considerably below the bottom of the harbor or canal, their toes ought to have a good catch besides the anchors. If there is a rock foundation, it looks as if cribs sufficiently wide, with a good catch for the toe, are a good construction after they have

well settled and gotten into a permanent shape. A concrete and stone wall for the portion above the water line, and interwoven with steel beams and rods, gives a lasting construction.

RETAINING WALLS,

or wharves in front of warehouses, act in most cases only as fenders to keep the ships and blows away from the building. These buildings are or ought to be built on independently constructed piers.

OUTER HARBOR.

Well, what are we going to do with it? Is it only to serve as a protection for the beach and the mouth of the river, or will it also cause a new and large development of docks and wharves along the shores of Lake Erie inside of it? We will hope the breakwater will be strong enough to withstand the severe storms which at times occur. On the seacoast, where a much heavier swell develops, it looks at times as if nothing could withstand the power of the furious waves.

In England, a few years ago, I saw at the mouth of the River Tyne how the waves had struck the top of the breakwater or mole and had shifted a top layer of concrete apparently 100 feet long and 6 to 8 feet thick. It had torn it loose and turned it around as if a turntable. There is a stretch of frontage on the lake shore three to four miles long—not a dock built out from it. Nearly all this frontage is owned by the railroads. What they will do is, of course, their own business, but we can clearly see it will cost considerable money to build walls or docks. It appears now that the business which can be expected will be loading and unloading of flour, lake package freight, shipping of coal, discharging of timber, etc. A pile dock of considerable width, well strengthened and fendered toward its outer end or pier head, is the most economic construction. It is also the quickest to construct. The construction is simple, so I will not try to describe it. In some cases it may be profitable to sink crib bulkheads and fill the excavated material behind. A strong pile and sheet piling bulkhead may also be found good economy, tying the opposite sides well together, something like cofferdams, the material dredged in the vicinity to be used to fill. Where cribs are used, a bed made from broken stone of good thickness and width is worth considering.

About twenty years ago, when I was employed in Norway in building a bulkhead and wharf, it was located at the mouth of a small river as this entered into a fairly well-sheltered bay. We drove a row of piles about 4 feet centers as a front. About every

other one of these piles was anchored back to several piles driven on a slant. The full depth was dredged in front of the piles. Great panels, made of double plank, were pushed down back of the piles, forming a wall. They were held down by being pushed under a girth bolted to the back of piles at water line. Dredged material was unloaded back of these piles up to a height of about 7 feet above water. We charred all the front piles before they were driven, burning a heavy coat of coal tar into the wood. This construction has stood exposure for twenty years and has been used as a lumber and light dock.

I have not yet seen any cast-iron piles being used in these waters. These, we know, have an auger-shaped point, which is bored into the sand or clay. These hollow cast-iron tubes could be strengthened with steel rods inside of them, and the cavity filled with concrete. A few of these piles bound together by steel beams would, in many cases, make a lasting and practical pier in the waters of our outer harbor. Cast iron withstands the action of fresh water for a very long time.

Along the Niagara River, especially between Black Rock and the Erie Basin, rock is encountered so near the surface that cribs with stone and concrete fronts will be the most frequently used.

Much of our harbor and river frontage is owned by the railroads. These have many considerations to take different from those of the municipalities. Even down on the seaboard, where we find their important terminals, very few wharves have been built from other material than from piles and timber. Therefore, I expect that here we also for a time will see mostly timber wharves built, though permanent structures will also become more frequent. The construction of a wide, well-paved street along the front, facing toward our new harbor, from the lighthouse to Stony Point, must be considered a necessity as well for the railroad as for the public. Such a well-paved street and boulevard, both for private driving and for heavy trucking, carrying people and loads to and fro, would create new business. The city ought to have on this stretch a wharf of its own, having fixed charges for the use of same either by the hour or day. A bridge or tunnel has to be provided by which this locality could be reached more conveniently than at present. It would be most desirable to cross the river and canal near the foot of Main Street or even farther out near the mouth of the river. A tunnel has very objectionable features. It is damp and very expensive, and a bridge is also an obstruction. Perhaps the best way would be to widen the Michigan Street bridges; make them more convenient, with wider ap-

proaches. These are matters worthy of the most intelligent consideration, and now is the time to consider them.

As I have said before, I have not presented this with much or any claim for originality in the matter treated, but its purpose is particularly to call your attention and to help to create an active sentiment. I think this Society ought to take the lead to form public sentiment and understanding in these matters. We would benefit from it as well as the city. The water frontage of our city has been neglected. The city ought to find out where it is, and plans should be outlined and framed as to what ought to be done.

In these lines of engineering, as in most others, the best to follow is the one where the dollars invested give the biggest returns.

Often we see work fall to pieces and decay; then we are inclined to believe something or somebody is wrong. Yet this apparent poor piece of work was probably the best for the occasion. It has served its purpose. America, with its growth, its vastness and its shifting conditions, could not be treated in construction as countries in Europe. When I first came here, I saw many railroads, with their timber structures, culverts, tunnels and bridges. They were not the structures which old civilized countries would have built, but to open up this great, large country to find new homes for the flow of immigrants several years would pass before much returns would come on the invested capital. Therefore, the trees standing near the right of way of the railroads was the material to use instead of expensive structures made from iron and high-class masonry. So it has been and will be yet for awhile also with the wharves. Timber and piles will yet be used for a long time.

The structures along our harbors in the near future will require more knowledge in their design. Loads are heavier, lands are more expensive, some material costs more, some less. There are, of course, special features characteristic of each locality. Thus, these fresh-water lakes differ from those of salt water. Down on the coast they have the teredo, which destroys piles and timber. Here we don't need to fear them, and timber, from water line down, is a splendid material for harbor structures. Also iron and steel corrode quicker near the ocean and salt water.

I will now close. I thank you for your patience. I had expected to present you with this some drawings showing the different wharf constructions, but I have not had time to do it. Further, as I began to prepare this little address, I gradually found myself more prepared to talk on generalities than on details. I thank you, gentlemen.

# Association of Engineering Societies.

Vol. XXVIII. | JANUARY, 1902. | No. 1.

## PROCEEDINGS.

### Engineers' Society of Western New York.

Minutes of Meetings of Engineers' Society of Western New York.

Regular Meeting, May 7, 1901.—Meeting called to order at 8.30 p.m.; the President in the chair. The following members present: Messrs. Haven, Diehl, Norton, Sikes, March, Tutton, Tresise, Roberts, Whitford, Eighmy and Buttolph.

It was ordered that the minutes of the last regular meeting be approved as printed.

The President announced that the Society had elected by their ballots Messrs. James Leland Averill, Horace P. Chamberlain and Eugene C. Hanavan.

Applications for membership were received, read and approved from Clarence R. Neher and Joseph Kuhn, and it was ordered that the same be referred to letter ballot.

The President informed the Society of the appointment, by the American Society of Civil Engineers, of a local Committee of Entertainment, during their Convention to be held in Niagara Falls during the latter part of June. He also informed the Society that the Society for the Promotion of Engineering Education would hold their Convention in Buffalo immediately after that of The American Society. They will hold their regular sessions in the Law Library, and have asked the use of our rooms in which to hold their Council. The President had replied that our Society would be very glad to have them make use of our rooms.

Mr. C. R. Neher's paper on Concrete Construction, read and discussed at the meeting of March 5, 1901, was further discussed by Messrs. Neher, Fruauff, Norton, March, Haven, Whitford and Tresise.

Meeting adjourned at 10.30 p.m.

Regular Meeting, June 4, 1901.—Meeting called to order at 8.30 p.m.; the President in the chair.

The following members present: Messrs. Haven, Diehl, Knapp, Norton, Bardol, Babcock, Cornell, March, Bassett and Fruauff.

The minutes of the last regular meeting were read and approved.

The President said that the Society had elected as members Mr. Clarence R. Naher and Mr. Joseph Kuhn, and the gentlemen would be notified of their election by the Secretary.

The President reported what the Pan-American Committee had done to date in regard to the entertainment of the American Society of Civil Engineers, the Canadian Society and the Society for the Promotion of Engineering Education.

The matter of holding meetings during the summer was discussed by the Society and referred to the President.

The matter of appointment of a Committee on Membership was discussed by the Society and on motion of Mr. Babcock, seconded by Mr. Knapp, the following resolution was unanimously adopted:

That the President be authorized to appoint Committees on Membership to serve as long as they can do any good, to be appointed at any time during his period of administration as he sees fit.

The President informed the Society, on behalf of Major Symons, that if any of the visiting Engineers wished to visit the new breakwater, he would be pleased to take them out on the government steamer.

Meeting adjourned at 10.30 P.M.

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AUGUST 1, 1901.—President Haven appointed Mr. Tresise to serve temporarily as acting Librarian in the absence of Librarian Knighton, removed to New York city.

As there was not a quorum present at the regular meeting in September, the President, with the written approval of all the members of the Executive Board, appointed the following named members as a committee to nominate officers to be balloted for at the annual meeting: A. W. Hoffman, George A. Ricker and W. B. Houck.

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REGULAR MEETING, OCTOBER 1, 1901.—Meeting called to order at 8.30 P.M.; the President in the chair.

The following members were present:

Messrs. Haven, Tutton, Knapp, Bardol, Powell, Kielland and Norton.

The minutes of the last regular meeting were read and approved.

It was moved and seconded that the dues of the Secretary for 1901 be remitted. Carried unanimously.

Application of Alfred William Thorn for Associate Membership was transmitted to the Society by the Executive Committee, and on motion was approved and referred to letter ballot.

The following resolution was proposed by Mr. Tutton:

*Be it resolved*, That Article 3, Section 2, of the Constitution be amended so as to read as follows:

Should any vacancy occur by resignation or otherwise, the President shall immediately call a meeting of the Executive Board who shall appoint a member of the Society to fill such vacancy for the unexpired term. Should such vacancy occur in the chair of the President, the Vice-President, in order of seniority, shall call such meeting.

Mr. Diehl moved the approval of the amendment. Seconded by Mr. Kielland.

The President was authorized to appoint Committee on Annual Meeting.

Meeting adjourned at 9.30 P.M.

Regular Meeting, November 5, 1901.—Meeting called to order at 8.30 p.m.; the President in the chair.

The following members present: Messrs. Haven, Tutton, Diehl, Norton, Morse, Kielland, Powell, Tresise and Whitford.

The minutes of the last regular meeting were read by the Secretary, and approved.

The President reported that the Executive Board had authorized him to appoint a collector to collect the unpaid dues, and on motion it was ordered that the President be empowered to continue the employment of the collector until the annual meeting.

The President reported that the Society had elected as an Associate Member Mr. Alfred William Thorn.

The President reported that he had appointed, as the Committee on Annual Meeting, Messrs. Morse, Humbert and Brackenridge. He had received letters from Mr. Humbert and Mr. Brackenridge, declining. The Committee was continued with power.

On motion, it was ordered that the business part of the annual meeting be held at 4 p.m., and adjourn to the regular time in the evening for the other entertainment.

The following report was received from the Nominating Committee:

*W. A. Haven, President, Engineers' Society of Western New York, Ellicott Square, N. Y.*

Dear Sir:—Under the authority of your appointment of us as a Committee to nominate candidates in your letter of September 14, we beg to submit the following list of nominees and hereby recommend its adoption:

President—W. A. Haven.
Vice-President—Chas. H. Tutton.
Director—Edward B. Guthrie.
Secretary—Charles S. Boardman.
Librarian—F. J. Tresise.
Treasurer—George B. Bassett.

Respectfully submitted,
(Signed) A. W. Hoffman, *Chairman*,
George A. Ricker,
W. G. Houck.

Mr. Guthrie, having heard that his name was to be proposed as Director, declined (per mouth of George C. Diehl) such nomination.

The Librarian suggested that the Society should purchase the new Engineering Index about to be published.

Mr. Tutton said he had told Mr. Tresise to get the Index if it could be purchased for $5.00, and if the Society would not take it, he would take it from him. Mr. Tresise was authorized to purchase the Index.

Meeting adjourned at 10 p.m. W. A. Haven, *President*.

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Annual Meeting, Buffalo, N. Y., December 2, 1901.—Meeting called to order at 4.15; the President in the chair. The following members present: Messrs. Haven, Tutton, Knapp, Sikes, Diehl, Norton, Babcock, Kielland, Tresise, George F. Morse and Kuhn.

The minutes of the last regular meeting were read and approved.

The reports of the Secretary and of the Treasurer were read and referred to a special committee.

The President appointed as such special committee Mr. C. E. P. Babcock.

Mr. Tutton, member of the Board of Management of the Association of Engineering Societies, made a verbal report of the questions that were before the Association.

The Librarian made his report and it was received and filed.

It was voted that the thanks of the Society be extended to Mr. Knapp and Mr. Tutton, members of the Society, for their additions to the library during the year.

The President.—In the matter of reducing our expenses, it has been suggested that we meet in some place where the rent is less and I think this matter should be taken up by the Executive Board, at once, to report at the next meeting.

Mr. Diehl.—In this connection I think we should sever our connection with the Association of Engineering Societies. The members who desire to receive the Journal can still do so by paying $3.00 per year. There is no reason why this Society should pay the amount we do.

The President.—No society can pay current expenses unless all the members pay their dues.

Mr. Tutton.—One of the chief objects in joining the Association was to get our papers published cheaper. It would cost us four times as much to publish a paper as it does to have the Association publish it.

Mr. Diehl.—It does not cost much to get our minutes printed, and it does not pay to belong to the Association just because we may have a paper to publish sometime, and we have not had many papers lately.

Mr. Tutton.—We should stop more promptly sending the Journal to members in arrears. It is not fair to the Association for us to move an increase in the salary of the Secretary and for us to withdraw.

It was ordered that the question of withdrawal from the Association of Engineering Societies be referred to the Executive Board.*

Mr. Babcock and Mr. Morse were appointed Tellers to canvass the vote cast for officers of the Society for 1902.

The Tellers reported that the following persons had received a majority of the votes cast:

President—Samuel J. Fields.†

Vice-President—Charles H. Tutton.

Director—T. Guilford Smith.

Secretary—George T. Roberts.

Librarian—Francis J. Tresise.

Treasurer—George B. Bassett.

The above-named gentlemen were declared duly elected.

The President.—The January number of the Journal is missing from our library, also the December, 1900, number of the "Proceedings of the American Society of Civil Engineers." The members are free to come to the Library to read or for consultation, but they are requested to take nothing away unless they bring it back. If any member has these books, he is requested to return them.

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* The Executive Board "laid on the table" this whole subject.

† Mr. Fields, having been nominated without his knowledge or consent and elected in opposition to his wishes, declined to serve as President for 1902; hence, the former President holds over until a successor is elected and qualified.

It was ordered that a committee of one be appointed to report at the next meeting of the Executive Board on the matter of change of quarters for the ensuing year.

The President appointed Mr. Bardol as such committee.

The President.—A proposed amendment to the Constitution has been read at a previous meeting and must be read at another meeting, and if approved by two-thirds of the members present the same is to be submitted to letter ballot. The proposed amendment was then read by the Secretary, as follows:

*Be it Resolved*, That Article III, Section 2, of the Constitution be changed so as to read as follows:

Should any vacancy occur by resignation or otherwise, the President shall immediately call a meeting of the Executive Board who shall appoint a member of the Society to fill such vacancy for the unexpired term. Should such vacancy occur in the chair of the President, the Vice-President in order of seniority shall call such meeting.

Unanimously approved.

On motion, meeting adjourned until 8 p.m.

## EVENING SESSION.

The Society met at 8 o'clock. In addition to those at the afternoon meeting there were present: Messrs. Roberts, Witmer, Ricker, Rogers, Bardol, Alverson, Boardman, Booz, Clark, Lewis, March, Eighmy, Wilson, McCulloh, Thorn, Neher, Dark, Powell and four visitors.

At 8.45 the company moved upstairs to the Ellicott Club.

During the evening the Chairman of the Pan-American Committee made a verbal report, and the Treasurer of that Committee made a written report. The reports were ordered to be printed in the minutes of the meeting.

Votes of thanks to retiring officers were passed.

Several gentlemen made short addresses, and the meeting adjourned at 11.30 p.m.

W. A. Haven, *President*.

Buffalo, N. Y., December 2, 1901.

## Report of the Secretary—Condensed.

### MEMBERSHIP.

| | |
|---|---|
| Total membership of all classes, December 1, 1900 | 66 |
| " " " " " December 2, 1901 | 79 |
| Increase during the year | 13 |

### MONEYS.

Received and deposited with the Treasurer:

| | |
|---|---|
| For Entrance fees | $100.90 |
| " Annual dues | 492.50 |
| " Key deposits | 2.50 |
| Total | $595.90 |

### MEETINGS OF THE SOCIETY.

Nine meetings of the Society have been held since December 1, 1900, with an average attendance of thirteen.

During the past year two papers were read before the Society,—"Concrete," by Mr. Neher, and "Docks," by Mr. Ricker.

MEETINGS OF THE EXECUTIVE BOARD.

Nine meetings of the Executive Board have been held since December 1, 1900, with an average attendance of five.

MINUTES OF MEETINGS, NOTICES, ETC.

During the past year 750 printed copies of minutes of meetings have been circulated, and 1500 notices of meetings have been sent. This has been done at a considerable expense to the Society, and it is a disappointment that the members to a large extent seem to have lost interest in the Society, as is shown by the data above, especially the facts that only two papers have been read before the Society in a year, and that the average attendance at the meetings has been only eight (exclusive of the members of the Executive Board).

This discouraging showing is somewhat offset by valuable work done by the Pan-American Entertainment Committee, which work, I understand, will be set forth in a special report.

As required by the By-Laws, the Secretary has received, audited through the proper authority and transmitted to the Treasurer, all bills against the Society. These bills will be tabulated in the Treasurer's report,—but it does not seem out of place in this report to call the attention of the Society to the fact that the amount required to conduct the Society on its present basis is in excess of its income,—and immediate steps must be taken, either to reduce expenses or increase revenues, or both.

I respectfully request that the President appoint a committee to examine the books of the Secretary before they are turned over to the newly elected officer.

Respectfully submitted,

G. C. DIEHL, *Secretary.*

BUFFALO, N. Y. December 2, 1901.

REPORT OF THE TREASURER—Condensed.

*Receipts:* PERMANENT FUND.

| | | |
|---|---|---|
| Cash on hand, December 1, 1900 | $172.36 | |
| Received from the Secretary | 100.90 | |
| Interest to date | 5.74 | |
| Total in bank | | $279.00 |

*Receipts:* CURRENT FUND.

| | | |
|---|---|---|
| Cash on hand, December 1, 1900 | $15.65 | |
| Received from the Secretary | 495.00 | |
| " " " Treasurer of Pan-Am. Com | 23.91 | |
| | | $534.56 |

*Disbursements:*

| | |
|---|---|
| Additions to Library | $21.45 |
| Annual meeting, 1900 | 12.45 |
| Assessments for Association of Engineering Societies | 69.00 |
| Rent of rooms | 238.00 |
| Notices and reports of meetings | 99.18 |
| Printing ballots for members | 13.42 |
| New bill heads and applications | 14.50 |
| Forward | $468.00 |

| | | | |
|---|---|---|---|
| Brought forward | $468.00 | | |
| Sundry expenses, account Pan-American Exposition | 27.71 | | |
| General expenses, postage, etc | 30.61 | | |
| | | $526.32 | |
| Cash on hand, December 2, 1901 | | 8.24 | |
| | | $534.56 | |

GEORGE R. SIKES, *Treasurer*.

BUFFALO, N. Y., December 2, 1901.

REPORT OF THE LIBRARIAN.

*To the Officers and Members of the Engineers' Society of Western New York:*

GENTLEMEN:—I beg to submit herewith my report as Librarian for the year 1901, as follows:

During the year there have been expended on the Library the following items, viz:

| | |
|---|---|
| Engineering Index | $3.20 |
| Association of Engineering Societies, Index | 2.25 |
| Topographical Maps | 2.00 |
| Table of Altitudes | .40 |
| *Engineering Magazine* | 3.00 |
| *Cassier's Magazine* | 2.75 |
| *Railroad Gazette* | 3.65 |
| Association Engineering Societies, back numbers of JOURNAL | .50 |
| *Railroad Gazette*, back numbers, to complete files | 3.70 |
| Total | $21.45 |

The following additions to the Library, other than by purchase, have been made:

| | |
|---|---|
| Exchanges | 197 |
| Donations, reports, etc | 167 |
| Catalogues | 8 |
| Total | 372 |
| Periodicals purchased, as above | 221 |
| Total additions during year | 593 |

The Library, as it now stands, is daily becoming more valuable to every member of the Society as a place of reference; but to make it more so, it is necessary that more money be expended in books, in bookcases and in binding printed matter that now exists in a loose state, to the end that the Library will become more attractive and in so doing the Society will become more of an attraction to each member.

The Society is indebted to our members, Mr. Louis H. Knapp and Mr. Charles H. Tutton for periodicals furnished the Society during the past year.

F. J. TRESISE, *Librarian*.

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REGULAR MEETING, JANUARY 7, 1902.—Meeting called to order at 8.15 P.M., the President in the chair. The following members present: Messrs. Haven, Tutton, Knapp, Roberts, Tresise, Norton, Diehl, Kuhn, Clark, Jackson, Babcock, Lewis, Wilson, Booz, Alverson, Buttolph and Bardol.

The minutes of the last regular meeting were read by the Secretary.

On motion of Mr. Diehl, the minutes were amended by erasing the statement that nothing of importance was done during the year.

The minutes, as amended, were approved.

The President.—The reports of the Secretary and Treasurer will be typewritten and placed in the minutes later. At the Executive Board meeting the matter of withdrawing from the Association of Engineering Societies was considered, and the subject-matter laid on the table indefinitely.

Mr. Bardol, who was appointed a Committee on Rooms, reported that he had visited the office buildings in search of different quarters, and found that for the same money as we are paying now we could not get as much accommodation as we are getting.

The President.—The Executive Board reports to you that the vote on the amendment to the Constitution was almost unanimously in favor of the amendment, and, therefore, it has been adopted.

Application was received from the Executive Board from William Roscoe Haven, and, on motion by Mr. Knapp, seconded by Mr. Diehl, the same was received and ordered to letter ballot.

The President.—The Executive Board has recommended that the dues of the Secretary be remitted for 1902.

On motion of Mr. Knapp, seconded by Mr. Norton, the recommendation was approved.

The President.—I have a resolution to offer, as follows:

"*Resolved,* That the Secretary be and hereby is directed to drop from the mailing list of the Journal of the Associated Engineering Societies the name of any person who is or shall be three months or more in arrears of dues to our Society; *provided,* that his name shall be returned to the list as soon as his dues are paid."

There is a provision in the Constitution that when a member is six months in arrears he loses his right to vote, but we still continue to pay his assessment to the Association.

Mr. Diehl.—If he pays up in a couple of months, will he get the back numbers of the Journal

The President.—Yes, sir.

Mr. Tresise.—It might be well to think of the time limit. Three months seems a little short.

The President.—I put six months in the resolution, but some of the members thought this was too long, so I changed it to three.

Mr. Knapp.—I think six months is too long. Three months is all right.

Motion seconded by Mr. Diehl. Carried unanimously.

The President reported that Mr. Fields had been notified of his election as President for 1902, but had informed the Society by letter that he declined to serve.

Mr. Clarence C. Lewis read a very able paper on "Modern Street Railroad Track Construction," which paper was illustrated by a number of views and was briefly discussed.

It was unanimously voted that Mr. Lewis be thanked for his very interesting paper which will be published in the Journal, with the discussion.

Mr. Tutton then read an abstract of an essay, brought out by correspondence, on his paper "The Laws of River Flow."

Meeting adjourned at 10.30 p.m.

George T. Roberts, *Secretary.*

## Engineers' Club of St. Louis.

536TH MEETING, JANUARY 8, 1902.—Held at the rooms of the Club at 1600 Lucas Place, at 8 P.M.; President Kinealy in the chair. Attendance, thirty-five members and twenty-two visitors. The minutes of the 534th and 535th meetings of the Club were read and approved. The minutes of the 318th, 319th and 320th meetings of the Executive Committee were read.

A communication from Mr. J. S. Braune concerning the award to him of the prize for the paper on "Tall Buildings" was read.

The Executive Committee was authorized to secure a die for the gold medal.

The lease of the new quarters in the Howard Building was read. The President was instructed by the Club to appoint two members for the Managing Board for the new quarters.

The applications for membership in the Club of Messrs. Burt Cole, Thomas Courtney Moarshead, John Vaughan McAdams and John Cooley Robinson were read.

Messrs. Thos. K. Peters and Alvin D. Reed were elected to membership.

The motion was carried that the President appoint a committee of three to revise the sections of the By-laws referring to the election of officers. Messrs. Russell, Colby and Flad were appointed for this committee.

The next order of business was a lecture by Mr. A. S. Johnson on "Some steel-concrete Constructions." The lecture was profusely illustrated by lantern slides and referred mainly to the use of expanded metal and corrugated bars in connection with concrete in the construction of walls, floors, arches, sewers, roofs and tanks. Mr. Johnson exhibited in the slides the methods of construction which were used, and gave some figures on the strength, weight and deflection of the various forms of construction.

The views included working drawings, photographs of work in process of construction and of completed work. The principles of the designs and the limitations of their use were explained in detail. A number of samples of expanded metal and corrugated bars and of these materials imbedded in concrete were exhibited to the Club.

The paper was heartily received by the Club and aroused considerable discussion, in which a large number of the members participated.

Meeting adjourned.

D. W. ROPER, *Secretary.*

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537TH MEETING, JANUARY 22, 1902.—Held at Lucas Place at 8 P.M.; with Vice-President Van Ornum in the chair.

The minutes of the 536th meeting were read and approved.

The report of the 322d meeting of the Executive Committee was read.

The report of the first meeting of the Managing Board of the Associated Technical Clubs of St. Louis was read.

Messrs. Burt Cole, John Cooley Robinson, Thos. Courtney Moarshead and John Vaughan McAdam were elected to membership.

The Secretary announced that the President had appointed the following committees:

Entertainment Committee—Mr. W. A. Hunicke, Chairman; Messrs. T. M. Post and Mark Bary.

Members of the Managing Board of the Technical Clubs of St. Louis—Messrs. B. H. Colby and J. L. Van Ornum.

The Chairman announced that a property list of the effects of the Club in the rooms at 1600 Lucas Place had been made out by the Managing Board, and that, in view of the importance of securing a complete list of the Club's property before removing to the new quarters, they would be glad to have the members look over the list and make corrections and additions.

On motion of Mr. Johnson, the Chair was instructed to appoint a committee of three to secure designs for the die for the gold medal and certificate of award in accordance with the report of the Committee on Prizes. The following were appointed on this committee: Messrs. Roper, Bryan and Colby.

The Chairman then introduced Mr. C. F. Longfellow, Commissioner of Public Buildings of the city of St. Louis, who addressed the Club on "The New St. Louis Hospital." The speaker gave a short historical sketch of the growth of the old city hospital from its beginning, in 1845, to its destruction by the cyclone, in May, 1896. A map of the city was exhibited, on which were shown the location of the present dispensaries, the temporary city hospital, the site of the new city hospital now under construction, and the site available for a hospital annex opposite the present Female Hospital.

The speaker reviewed the report of the commission of seven which was appointed some years ago to report on the needs of the city and to devise plans for a new hospital. The old hospital being destroyed during the existence of the commission, the site of the old hospital was recommended as the most suitable of the available sites for a new hospital. A plan of the arrangement of the buildings as recommended by this commission was shown, and the uses of the several buildings explained. A plan and several elevations of the arrangement of the building as finally adopted was also exhibited. The reasons for the changes from the plans of the commission were explained. The speaker described in detail the arrangement, uses and sanitary precautions adopted in the construction of the various buildings.

The buildings whose construction was authorized by existing ordinances were indicated. Attention was also called to the fact that the rate at which funds were at present available would not permit the completion of the buildings inside of ten or twelve years, and that the total capacity of the buildings as planned was less than the present requirements of the city. The hope was expressed that the amendments soon to be submitted to the voters of the city would include a scheme which would increase the funds available for the completion of the buildings and also permit a beginning on the hospital annex. The speaker also pointed out the opportunity afforded to the wealthy citizens to perpetuate their names and assist the city by donating funds for the erection of one or more of the five ward buildings contemplated by the plans, none of which have as yet been authorized.

In the discussion which followed, Mr. Wheeler and others participated.

In adjourning the meeting, the Chairman invited the members and guests into the adjoining rooms, where a lunch was served under the direction of the Entertainment Committee.

D. W. Roper, *Secretary.*

## Engineers' Club of Minneapolis.

152D MEETING, JANUARY 2, 1902.—Held at their rooms in the County Commissioner's office. This was the annual meeting of the Club.

After the usual order of business the reports of out-going officers were read. President Wm. W. Redfield reviewed the growth of the Club and the work done during the past year, calling attention to the new Constitution which had been adopted, and the increased interest of members in the programs.

Vice-President C. L. Pillsbury spoke on the subject of a higher grade of work and more recognition of the work of the Club members as a body.

The Treasurer's annual report showed a balance on hand January 2, 1902, of $53.35.

The Secretary reported on the year's work as follows: "At the beginning of the year 1901 we had 15 active members in good standing as follows: Burch, Carroll, Dealing, Durham, Fanning, Gillette, Graber, Hoag, Llewellyn, Pillsbury, Smith, Stack, Sublette, Stoopes and Redfield. During the year we lost three members by resignation and for non-payment of dues. We have added to this list 17 members as follows: Avery, Chalmers, Comstock, Crafts, Dustin, Gray, Illstrup, Lund, Pardee, Reidhead, Rice, Robertson, Shepardson, Slocum, Tate, Wheeler, Williams, making a total of 29, some of whom, however, had formerly belonged to the Club (see official list of members, JOURNAL, January, 1902). We have no corresponding members. We have five honorary members as follows: Geo. H. White, Worcester, Mass.; John H. Barr, Cornell University; W. I. VanDuzee, John W. Kendrick and J. T. Fanning, of Minneapolis.

D. C. Washburn, transitman, City Engineer's Office, Minneapolis, and S. M. White assistant engineer, Great Northern Railway, West Superior, Wis., become active members beginning with the year 1902.

Of our 29 active members 16 may be classed as civil engineers, 8 as electrical engineers and 5 as mechanical engineers. More than one-half of our members are graduates from engineering colleges.

During the year 1901 we held 12 meetings as follows:

140th meeting, at which Wm. W. Redfield read a paper on the "Isthmian Canal."

141st meeting, in connection with a banquet at the Commercial Club, at which inaugural addresses were given.

142d meeting, in connection with a Club dinner at the Guaranty Restaurant. W. S. Pardee presented a paper on "Methods of Scientific Study," the most valuable paper presented during the year.

143d meeting, at which J. T. Fanning presented a historical paper on "Early Transportation Canals," which was published in the JOURNAL. Mr. E. H. Tromanhauser presented a paper on "Grain Elevator Construction." He has also loaned the Club a complete and very valuable set of the U. S. patent office records on the subject, which are still on file.

144th meeting, at which Mr. Fanning's paper was discussed, and our new Constitution was adopted.

145th meeting, at the Minneapolis General Electric Company Sub-Station, where F. E. Reidhead presented a paper describing the sub-station, after which it was inspected by the members.

146th meeting was spent in an inspection of the William Bros Boiler Works on Nicollet Island, Minneapolis.

147th meeting, for an inspection of the new Pioneer Steel Elevator, where Mr. E. H. Tromanhauser acted as host.

148th meeting was without formal program.

149th meeting, at which a paper was presented by President W. W. Redfield on "Cost of Water Mains," and one by W. S. Pardee on "Specification Making."

150th meeting, at which a paper was read by S. M. White on "Breakwaters." Photographs, blueprints, etc., were shown by D. C. Washburn on some preliminary work at the Sault Ste. Marie Canal. The paper on "Breakwaters" will be published in 1902 JOURNAL.

151st meeting was spent in an inspection of the Twin City Telephone Company's South Branch Exchange.

Our average attendance during 1901 was 12.

We expect to have permanent quarters in the new City Hall during the coming year, when our library, which is scattered, will be placed in good condition.

The Secretary suggests that two or more short papers be presented at each meeting, thus dividing the work required in preparing the papers; also calls attention to the fact that a most important work in the future will be that of the committee who will prepare technical programs; for no one program will be of interest to all our members.

The following officers were elected for the year 1902:

President—Wm. R. Hoag.

Vice-President—H. B. Avery.

Secretary and Treasurer—Edw. P. Burch.

Librarian—J. E. Carroll.

Representative in the Association of Engineering Societies as member of the Board of Managers—Geo. W. Sublette.

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## Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 13, 1902.—The annual meeting of the Civil Engineers' Society of St. Paul was held in the parlors of the Windsor Hotel, Monday evening, January 13, at eight o'clock; President Powell in the chair.

The usual routine business was transacted, after which the reports of officers for the past year were read and approved, after which the annual election of officers for the coming year were held and resulted as follows:

For President—A. W. Münster.

For Vice-President—A. R. Starkey.

For Secretary—G. S. Edmondstone.

For Treasurer—A. H. Hogeland.

For Librarian—C. A. Winslow.

For Representative, Board of Managers; Association of Engineering Societies, Geo. L. Wilson.

Application of Mr. L. P. Wolff f r membership was read, and upon ballot he was elected a member of the Society.

The reports read show that the Society is in a flourishing condition, both numerically and financially.

Meeting adjourned to the café of the Windsor Hotel, where a love feast was held, the dainties enjoyed and the hours passed in a most pleasant manner. The following toasts were proposed and responded to, viz:

"The St. Paul Society of Civil Engineers," Mr. E. E. Woodman.

"The Engineers' Club of Minneapolis," Messrs. Hoag and Sublette.

"Electrolysis," Mr. Oscar Claussen.

"The Civil Engineer," Mr. G. S. Edmondstone.

"Ancient and Modern Bridge Building," Mr. A. W. Münster.

"Municipal Engineering," Mr. Geo. L. Wilson.

The meeting was thoroughly enjoyed by all members and visitors and adjourned amid hopes of prosperity for the ensuing year, and for the years to come.

G. S. Edmondstone, *Secretary.*

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## Boston Society of Civil Engineers.

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Boston, Mass., January 22, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m.; President L. B. Bidwell in the chair. Sixty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. John J. Kirkpatrick and Joseph W. Walker were elected members of the Society.

On motion of Mr. A. H. French, the President was requested to appoint a committee of three to report to the meeting the names of five members to serve as a committee to nominate officers. The President appointed as the committee Messrs. A. H. French, A. H. Howland and G. A. King. Later in the meeting this committee reported as members of the Nominating Committee Messrs. L. F. Rice, F. C. Coffin, F. O. Whitney, G. T. Sampson and E. A. W. Hammatt.

On motion of Mr. Brooks, the report was accepted and the members named were chosen as the committee to nominate officers.

On motion of Mr. French, Mr. Henry Manley was appointed a committee with full powers to make arrangements for the annual dinner of the Society.

On motion of Mr. Holmes, the thanks of the Society were voted to the Department of Engineering of Harvard University and to Prof. H. L. Warren of the Department of Architecture, for courtesies extended to members of the Society during the visit to the Harvard University, Pierce Hall and the Architectural Building at Harvard this afternoon.

Mr. James H. Macdonald, Highway Commissioner of Connecticut, read the paper of the evening, entitled "From City Street to Country Road." The paper gave a very interesting account of the writer's experience in road construction in Connecticut during the past seven years. At its conclusion Mr. Macdonald submitted to a lengthy catechism in road construction.

On motion of Mr. FitzGerald, the thanks of the Society were voted to Mr. Macdonald for his interesting and instructive paper.

Adjourned.

S. E. Tinkham, *Secretary.*

# Association of Engineering Societies.

Vol. XXVIII. FEBRUARY, 1902. No. 2.

## PROCEEDINGS.

### Technical Society of the Pacific Coast.

Regular Meeting, January 3, 1902.—Called to order at 8.30 p.m. by Past President Grunsky. The minutes of the last regular meeting were read and approved.

The Chairman announced the following election upon due count of ballots:

Geo. H. Wallis, of San Francisco, and Geo. F. Day, of San Francisco.

Dr. F. W. Riedler, a scientist, addressed the Society on the subject of "Life-Saving Kites," exhibiting various apparatus for the purpose of carrying life lines and bodies through the surf to an object at sea.

The Secretary notified the Society of the following facts, which will be circulated to each member by mail:

The dues for the current half year are now payable, and the collector will call upon all resident members for payment.

Notice is hereby given that the resident members of the Technical Society are also members of the Mechanics' Institute, and entitled to all its privileges.

The dues to the Society hereafter are 50 cents per month for all classes of membership; in addition to this the Institute will collect its dues, which are $1.50 per quarter, and now payable for two months, from January 1 to March 1, 1902.

The non-resident members of the Society, while not members of the Institute, are entitled to all the courtesies of visiting members while in San Francisco, and are requested to call at the Library, identifying themselves with a visitor's card, which will be furnished them.

The privilege of taking books from the library is granted only to members paying the quarterly dues. The admission fee of the Institute has been paid by the Technical Society for all resident members who have heretofore paid $1 per month.

Any associate may become a member of the Mechanics' Institute by notifying the Secretary of the Technical Society.

The Nominating Committee submitted the following report, and the Secretary was instructed to have tickets prepared to be mailed to all voting members in good standing:

For President—Luther Wagoner.

For Vice-President—D. C. Henny.

For Secretary—Otto von Geldern.

For Treasurer—E. T. Schild.

For Directors—S. G. Irving, Stetson G. Hindes, Adolph Lietz, Franklin Riffle and C. B. Wing.

The report was signed by C. E. Grunsky, Chairman of the Nominating Committee, and the members Hermann Barth, James D. Mortimer, Arnold d'Erlach and Hubert Vischer.

The Chair appointed the following judges for the Annual Election: H. A. Brigham and H. I. Randall.

Meeting adjourned. OTTO VON GELDERN, *Secretary.*

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ANNUAL MEETING, JANUARY 17, 1902.—Called to order at 8.30 P.M. by Past President Marsden Manson.

The Secretary stated the purpose of the meeting, which is held in accordance with the Constitution of the Society, to elect a ticket of officers for the ensuing year.

After carefully scrutinizing the ballots, three of them were rejected, two because they were from associates and one from a member too far in arrears in dues to allow him the privilege of voting.

The tellers, or judges, appointed by the chair thereupon reported—H. A. Brigham and H. I. Randall—and the ballots were given to them to be opened and counted.

After beginning the count, four more ballots were handed in by the Society's office clerk that had been received during the day, but had been forgotten in giving the Secretary the day's mail. Upon motion put by the Chair, they were admitted in the count then proceeding.

Upon completion the judges made the following report:

Total vote cast, 68.

For President—D. C. Henny, 49; Luther Wagoner, 19.

For Vice-President—F. G. Hesse, 43; D. C. Henny, 19; Marsden Manson, 1; Luther Wagoner, 4.

For Secretary—Otto von Geldern, 68.

For Treasurer—E. T. Schild, 68.

For Directors (5 of them)—Stetson G. Hindes, 68; Samuel C. Irving, 67; Adolf Lietz, 68; Franklin Riffle, 68; C. B. Wing, 68.

Report signed by

H. A. BRIGHAM and

H. I. RANDALL.

Upon motion the following officers were declared duly elected for the year 1902, and the Secretary instructed to inform them of the fact and call the Directory together for a business meeting:

President—D. C. Henny.

Vice-President—F. G. Hesse.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Stetson G. Hindes, Samuel C. Irving, Adolf Lietz, Franklin Riffle and C. B. Wing.

The Secretary asked for further time to prepare his report, and the Treasurer submitted the following:

TREASURER'S REPORT FOR THE YEAR 1901.

I beg to submit to the Board of Directors of the Technical Society of the Pacific Coast the following report:

| | | | |
|---|---|---|---|
| January 10, 1901. Cash on hand | $3.93 | | |
| " in bank as per bank book | 209.67 | | |
| | | $213.60 | |
| January 10, 1902. Cash received during the year | | 1,262.50 | |
| | | | $1,476.10 |
| Cash expended during the year, January 10, 1901, to January 10, 1902 | | $1,187.50 | |
| January 10, 1902. Cash on hand | $47.09 | | |
| " in bank as per bank book | 241.51 | | |
| | | 288.60 | |
| | | | $1,476.10 |

THE ITEMIZED RECEIPTS ARE AS FOLLOWS:

| | | |
|---|---|---|
| Cash on hand | $3.93 | |
| " in bank | 209.67 | |
| Dues | 1,195.50 | |
| Admission fees | 55.00 | |
| 3 Diplomas | 4.50 | |
| Donations | 7.50 | |
| | | $1,476.10 |

THE ITEMIZED EXPENDITURES ARE AS FOLLOWS:

| | | | |
|---|---|---|---|
| Rent, 11 months | | $330.00 | |
| Salary of Secretary, 12 months | | 180.00 | |
| Janitor and elevator, 11 months | | 26.50 | |
| Library work | | 45.00 | |
| Collector | | 68.40 | |
| 4 Assessments of Association of Engineering Societies | | 282.00 | |
| Books and subscriptions | | 38.15 | |
| Bookbinding | | 7.35 | |
| Printing, stenographing and typewriting | | 85.75 | |
| Stationery, postage, mailing, embossing, etc. | | 99.35 | |
| Excursion to Arch Rock | | 25.00 | |
| | | $1,187.50 | |
| Cash on hand | $47.09 | | |
| " in bank | 241.51 | | |
| | | 288.60 | |
| | | | $1,476.10 |

E. T. SCHILD, *Treasurer.*

The report was received, placed on file and spread upon the records. Meeting adjourned.

OTTO VON GELDERN, *Secretary.*

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REGULAR MEETING, FEBRUARY 7, 1902.—Called to order at 8.30 P.M. by President Henny. The minutes of the last meeting were read and approved. The following names were proposed:

For members—Thos. Smith, Draftsman Light House Department, San Francisco; proposed by A. Ballantyne, Otto von Geldern and Milo Hoadley. J. G. McMillan, County Surveyor, San Jose; proposed by C. B. Wing, Adolf Lietz and Otto von Geldern.

Mr. John Richards, Past President of the Society, addressed the members on the subject of "Compensation of Skilled Labor," which was discussed by Messrs. Geo. W. Dickie, A. H. Sanborn, Hubert Vischer, S. C. Irving and others.

Adjourned. OTTO VON GELDERN, *Secretary.*

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## Louisiana Engineering Society.

NEW ORLEANS, JANUARY 11, 1902.—The annual meeting of the Louisiana Engineering Society was called to order on this date at 8.30 o'clock P.M. President Kerr presiding and twenty-one members in attendance.

The minutes of the last meeting were read and approved.

The Committee appointed to prepare resolutions on the death of Mr. Thos. L. Raymond submitted a memoir and resolutions. The memoir is printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The resolutions, as follows, were introduced and passed:

*Resolved,* by the Louisiana Engineering Society, in regular meeting assembled:

That in the death of Mr. Thomas Laidlaw Raymond the Society mourns the loss of a faithful, active and zealous member.

That the profession is deprived of the service of an untiring and energetic worker, a recognized authority on hydraulic and sanitary engineering, and an engineer of spotless character and reputation; be it further

*Resolved,* That the account of his professional life be filed with our records, and this and these resolutions be forwarded to his family as an expression of the respectful sympathy of the Society.

The Chair made the following announcements on behalf of the Board of Directors:

The resignation of Mr. Tutwiler as member of the Board of Directors.

One application for membership on file and preliminary list ordered.

The Board refers action of giving a smoker to the Society.

The matter of employing an Assistant Secretary was referred to the new administration for action.

The annual report of the Board of Directors transmitting the reports of the Secretary-Treasurer and House Committee was read and ordered filed.

A motion was made and passed that the rooms of the Society be tendered Captain W. J. Hardee for use in entertaining his regiment during the month of February.

The election of officers was next declared in order and the Chair announced that Mr. A. C. Bell, one of the nominees for President, was ineligible for election. The Chair asked what action the Society would take in the matter.

It was moved and adopted that the ballots be opened and that the eligible candidate receiving the largest number of votes be declared elected.

Thirty ballots were cast, and the following gentlemen were elected:

President—Alf. F. Théard.

Vice-President—W. B. Wright.

Secretary—G. W. Lawes.

Treasurer—R. E. DeBuys.

Director—Prof. John M. Ordway.

For representative on Board of Management of Association of Engineering Societies—F. M. Kerr.

The Chair then called attention to the vacancy in the Board of Directors caused by the resignation of Mr. Tutwiler.

The following nominations were made to be voted on at the next meeting for Director to fill Mr. Tutwiler's unexpired term: A. C. Duval, Ernest D. Ivy.

An address was delivered by Mr. Kerr, the retiring President, as below.

At the conclusion of the address a vote of thanks was tendered Mr. Kerr for his valuable paper.

The new President, Mr. Alf. F. Théard, was then escorted to the chair, and after a short, eloquent speech of acceptance a recess was ordered, and the healths of the retiring and incoming Presidents were drunk.

The meeting adjourned at 10.10 P.M.

G. W. LAWES, *Secretary.*

### ADDRESS OF MR. KERR, RETIRING PRESIDENT.

GENTLEMEN,—It devolves upon me, to-night, under the Constitution of our Society, to deliver an annual address.

Frankly, this is a misfortune for all of us, for if there be one in our ranks less ambitious and as little qualified to deliver an address, annual or otherwise, than your humble servant, he is still to be heard from.

While I can honestly and truly assure you that each and every service I have been permitted to render you, during the past twelve months, has been accorded with pleasure, and that each and every session with you has been greatly enjoyed and appreciated, as each month slipped by and brought me to closer consider what might be expected of me in an annual address, the stronger the doubt in my mind grew as to whether, for all the other pleasures and honors combined, I could have been induced to accept your flattering elevation to office.

To be law-abiding, however, is the first duty of every good citizen in our Commonwealth, and to be gracious the dominating feeling in the breast of every gentleman.

Our law says that, serving as your presiding officer, I must address you on this occasion, and your kind and considerate treatment of me during the past year commands me to be gracious in complying, no matter how poorly I may succeed in entertaining you.

Admitting the early consciousness of all of which, the deduction might be plain that the path before me had been well reconnoitered, and that I should, in spite of any disclaimer on my part, now be well prepared to travel it, but, after all is said on the score advanced, I can further honestly confess that I still stand before you to-night, very much in the same plight as the poor wayfarer who was in sore doubt about his road and asked directions of a facetious rustic whom he happened to pass on the way. "Well," said the latter, "you just go right straight ahead on this road, old man, till you get to the top of a hill. At the top of this hill the road forks, one prong turns to the left, another to the right, and a third goes straight on. Do you catch on?" "Yes, and which fork, pray, shall I follow?" asked the traveler. "Don't 'pear to me to make a dog-goned bit of difference, old hoss, you're lost, anyhow," shouted back Mr. Rusticus, who had by that time reached a safe distance.

And thus, having passed the twelfth stage of my year's journey as President, the road up to the forks, with your able assistance, having been made plain and easy progress for me, I nevertheless find myself at the top of the hill at a loss to select any path—in the field of science, literature or art—in all of which an engineer is generally expected to be versed, to which I feel I could do justice and in which I could hope to interest you to follow, and am compelled to fall back upon the beaten track of description, and as our worthy brothers in journalistic circles to-day put it, simply give you a story.

The story in my mind relates to some facts and incidents in the history of a certain vast resource in our State with which I have been brought personally in contact, and which, though quite frequently touched upon in the daily press, within the past year, does not appear to me to have been as clearly and fully written up as the subject deserves.*

## Engineers' Club of St. Louis.

538TH MEETING, FEBRUARY 5, 1902.—Held at 1600 Locust Street at 8 P.M. with President Kinealy in the chair. Present, thirty-eight members and twelve visitors.

The minutes of the 537th meeting were read and approved.

The proceedings of the 323d meeting of the Executive Committee, and the minutes of the second meeting of the Governing Board were read.

The application of Messrs. Geo. D. Rosenthal, Wm. M. Hand, Frederick W. Hulme, Reno DeOrville Johnson were read and referred to the Executive Committee.

The President then introduced Mr. Henry Rustin, mechanical and electrical engineer of the Louisiana Purchase Exposition Company, who addressed the Club on the subject, "Exposition Engineering Problems." Mr. Rustin outlined the power requirements of an exposition which includes two-wire and three-wire direct current circuits of several different voltages; single-phase, two-phase and three-phase alternating current of several different voltages and frequencies, water, compressed air, illuminating gas, and possibly natural gas and acetylene. Provision must be made for water for fountains and sanitary purposes, power for intramural railways, cranes, elevators and moving exhibits; lighting for police purposes, illumination and decorative purposes. The decorative lighting at recent expositions has far outgrown the requirements of illumination and has been made one of the most attractive features.

As an exposition power plant has a life of only six or seven months, the methods used in the solution of the problems which arise are radically different from the methods in ordinary commercial practice. On account of the time required in obtaining and installing the power equipment the amount of power to be supplied must be settled upon at least a year in advance of the opening, and the decision once made is not subject to any material changes. The methods of construction must be inexpensive and at the same time capable of rapid installation. The work must be safe, pleasing to the eye, and the service must be continuous during the exposition.

*Mr. Kerr's account of the sulphur deposits of Calcasieu Parish is published as a paper in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Such nuisances as smoke, soot, escaping steam or other vapors, offensive odors or disagreeable noises are not permitted.

In the discussion which followed the reading of the paper, Messrs. Johnson, Fish, Freeman, Hand, Humphrey, Robinson, Wheeler, Kinealy and others participated.

The meeting adjourned. D. W. Roper, *Secretary.*

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539th Meeting, February 19, 1902.—Held at 1600 Locust street, at 8 p.m., with Vice-President Van Ornum in the chair. Present, nineteen members and six visitors.

The minutes of the 538th meeting were read and approved.

The minutes of the 324th meeting of the Executive Committee were read.

The applications for membership of Messrs. Henry Rustin and Robert E. Einstein were read and referred to the Executive Committee.

Messrs. Geo. D. Rosenthal, Wm. M. Hand, Frederick W. Hulme and Reno DeOrville Johnson were elected to membership.

Mr. S. B. Russell, chairman of the committee appointed to revise the rules relating to election of officers, made a report for the committee and submitted a draft of the proposed amendments. On motion it was ordered that the amendments be made a special order of business for the meeting of March 19, 1902, and that the Secretary, in mailing to members the notices for the next meeting, notify the members of the proposed action, as required by Section 13 of the By-Laws.

The Chairman then introduced Mr. E. R. Buckley, Missouri State Geologist, who read a paper on "Highway Construction." The speaker described the various forms of construction, the several materials used for paving and their uses and limitations. This paper will be printed in full in the Journal.

In the discussion which followed the reading of the paper, Messrs. Wheeler, Flad, Lubberger and others participated. Mr. Wheeler took issue with the speaker on the testing of paving brick and favored the rattler test rather than the absorption test. Mr. Flad stated that St. Louis was an exception to the general rule given by the speaker, and sent their engineers on visits of inspection to other cities. He also outlined some of the improvements that had been decided upon for the streets of St. Louis.

The Chairman announced that at the next meeting Mr. R. H. Klauder would read a paper on "Storage Batteries."

The meeting adjourned. D. W. Roper, *Secretary.*

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## Boston Society of Civil Engineers.

Boston, Mass., February 5, 1902.—A special meeting of the Boston Society of Civil Engineers was held in Room A, Tremont Temple. The meeting was called to order by President L. B. Bidwell at 7.40 o'clock p.m.; Mr. E. W. Howe acting as Secretary. Fifty members and visitors present.

The President introduced Mr. Joseph P. Frizell who read a paper entitled "Tidal Scour in Harbors, or the Function of Tidal Basins, with special Reference to the Harbor of Boston." The paper was discussed

by Messrs. F. W. Hodgdon, X. H. Goodnough, W. M. Brown, R. A. Hale, F. P. Johnson and G. T. Sampson, of the Society, and by Mr. Woodward Emery, Chairman of the Board of Harbor and Land Commissioners, and Mr. W. B. de las Casas, Chairman of the Metropolitan Park Commission.

At 9 o'clock P.M. the meeting adjourned.

E. W. Howe, *Acting Secretary.*

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Boston, Mass., February 19, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President L. B. Bidwell in the chair. Fifty-four members and visitors present.

The record of the last regular meeting, and that of the special meeting of February 5th, were read and approved.

Messrs. Waldo A. Learned, Charles A. Stone and Edwin S. Webster were elected members of the Society.

On motion of Mr. Holmes, the thanks of the Society were voted to the Edison Electric Illuminating Company and to the Boston Elevated Railroad Company for courtesies extended this afternoon on the occasion of the visits to the power plants of those companies, on Atlantic Avenue.

On motion of Mr. Brooks, the thanks of the Society were voted to Mr. F. E. Adams for the interesting paper read by him at the informal meeting of the Society held on the 12th inst.

Mr. H. H. Clayton, of the Blue Hill Meteorological Observatory, was then introduced, and gave an exceedingly interesting talk, illustrated with numerous lantern slides, on "Exploration of the Air with Kites."

At the conclusion of the talk, on motion of Mr. A. H. French, a vote of thanks was passed to Mr. Clayton for his kindness in appearing before the Society and giving so valuable and interesting an account of the latest achievements in kite observations.

Adjourned. S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

Vol. XXVIII. **MARCH, 1902.** No. 3.

# PROCEEDINGS.

## Boston Society of Civil Engineers.

### Twentieth Annual Dinner.

The twentieth annual dinner of the Boston Society of Civil Engineers was held at the Hotel Vendome, Boston, Tuesday evening, March 4, 1902, and was attended by 151 members and guests. An informal reception preceded the dinner, which was served at 6.30 o'clock.

At the after-dinner speaking, the President of the Society, Mr. Lawson B. Bidwell, acted as toastmaster, and introduced the first speaker and chief guest of the evening, Justice David J. Brewer, of the United States Supreme Court. Justice Brewer spoke substantially as follows:

"A six-year-old grandson of mine, who is sadly lacking in reverence, said to his mother the other night, 'Mother, where did you get me, anyway?' She replied, 'Why, Jimmie, God sent you to me.' 'He did!' exclaimed the boy; 'pshaw, I thought I was born in Boston.' Evidently the youngster labored under the impression that Boston had little need of the Almighty's assistance for what it produced or else that the Almighty had little to do with Boston. Coming before you this evening with no such irreverent spirit, yet not entering into any discussion of how much the Almighty has had to do with Boston, I am here to say that the engineers have had a great deal to do with it; that through their skill and ability the way of approach to this metropolis of New England has been made easy. Through them commerce has found here magnificent possibilities. They have worked wonders in securing the comforts of home, the riches of education and the beatitudes of art. What Boston would have been without the engineers may be an interesting question for those who love to study the descending possibilities of life, and who feel at home in Dante's Inferno, but as for me a pleasanter inquiry is how much does the city of Boston owe to the engineers for all that gives it its glorious name in the life and history of this republic.

"Although you are incorporated as the 'Boston Society of Civil Engineers,' yet your constitution makes eligible to membership 'civil, mechanical and mining engineers and other persons belonging to the technical professions.' When I look at your roll of members, I find you are not confined to Boston, nor even to Massachusetts, but scattered through

the length and breadth of the republic. Nay, more; both hemispheres and each of the five continents is represented. And I suppose that ere long you will take possession of those as yet legally unlocated and indescribable regions, Porto Rico and the Philippines. No pent-up Utica contracts your powers. You reach to the uttermost parts of the earth. No wonder this great republic is manifesting a marvelous amount of expansion when even a local corporation thus extends its reach. Instead of being composed of only civil engineers, you have all sorts of intellectual people—engineers of every name and style, inspectors, superintendents, architects, landscape gardeners, professors, officers of insurance companies, topographical surveyors, treasurers, bankers, brokers and draftsmen. Indeed, about the only professions that are not named in your list are medicine, law and theology. There are no doctors, and yet you appear to be a remarkably healthy body of men. I see no lawyers on your rolls, and still you look as though you were reasonably honest. There are no ministers, and yet I doubt not your moral character is at least on a par with the average Boston morality.

"I have been told that there is in some of the illiterate mountain regions of the South and West a religious sect known as Hard-shell Baptists, one of whose tenets is that the Almighty made the world just as He wanted it, and that every change on the face thereof, even to the building of a turnpike road, is an act of disobedience to His supreme will. Tested by the tenets of that sect, the engineers must be very wicked, especially those who live and work in New England. But here again I am for the engineers and against the Hard-shell Baptists. Why was the face of the earth made so rough and irregular? Obviously, as I think, that it might call forth all the energies and efforts of man to make it fit for his home; for as he builds his home so he builds himself. Wherever the Almighty has done the most there has been the least progress of the race. Indeed, if we may credit the story of the Garden of Eden, which, as it is said, 'gave man all to live with and nothing to live for,' the first thing man did when placed in the garden was to steal apples; whereas the best and noblest of the race have been developed on those shores and in those countries where unrelenting toil was the condition of life. This fact indicates the purpose of the Almighty. Man was not made for the earth, but the earth for man, and only where his surroundings compelled the earnest struggles were developed the highest capacities of his being. Talk about the curse of labor! If Eve's curiosity drove man out of the toilless garden, I, for one, bless the old lady for it. So, despite the theory of the Hard-shell Baptists, I say thank God for the engineering spirit which bids man grapple with the broken surface of the earth and work upon it until 'every valley shall be exalted, and every mountain and hill shall be made low; and the crooked shall be made straight and the rough places plain,' for thus 'the glory of the Lord shall be revealed, and all flesh shall see it together.'

"I have said the pleasant inquiry was, How much does Boston owe the engineers? And that is only a fragment of the larger question, How much are humanity and civilization indebted to them? And the answer is that they have made possible the greatness and grandeur of our civilization. If it were not for the facilities of transportation and travel, for which we are indebted to them, how stagnant would be the life of the race!

"Whence come all the decorations of our homes, the abundant supplies that fill our stores and warehouses? Nay, more; whence come the homes, the stores and the warehouses themselves? They do not grow. On the rocky shores of New England may tower hill and mountain, grand in gloom and glory; pine forests may lift their heads amid storm and sunshine. No man built them. But the Pilgrim Fathers, when they landed on these shores, found no homes, nor stores, nor warehouses, and none through all the subsequent years have grown through any of the processes of nature. The visible Boston, at least, is the handiwork of man. Nor could he find either above the soil, growing and organic, or beneath it, lifeless and inorganic, all that was necessary to make the completed city. From the four quarters of the globe have been brought, over ways which the engineer has made, the material which has passed into the glorious vision which greets the eye as it looks down upon the capital city of New England. In all the development of New England the engineer has been the right arm of commerce. Indeed, without him commerce could not have been, and without commerce, what would New England be? There is scarce a thing on this famed peninsula of Boston which is not due to the work of the engineer. I will not say everything, for I believe no one holds him responsible for the narrow and crooked streets that traverse the eastern part of the city. Accurate history attributes them in the first instance to the homeward wanderings of the cross-eyed cow with the crumpled horn.

"Returning from the cow to the engineer, let me notice briefly what his work on the highways of the globe means for the race; for to him we look for whatever is done in the permanent structure of those highways and in determining the best modes of their use.

"How little we realize the marvelous changes which are going on in the facilities for transportation and travel, and how little also do we appreciate the significance of that fact in its effect upon the conditions of life. All these changes have come since steam and electricity have been introduced as motive powers. Since their advent, what an increase in capacity, speed and cheapness! Think, for a moment, of the immense volume of goods and merchandise brought into this city by rail in a single day, coming, some of it, from distant parts of the continent, and then add to that the other great volume coming by water from the farthermost parts of the earth, and tell me how many wagons of the largest capacity ever known, and how many animals of the greatest strength, and how many of the sloops, schooners and three-masted vessels of a century ago it would take to transport these two great volumes of goods and merchandise into this city. There would hardly be room enough within its extensive limits for the wagons which would be necessary to make this transportation, and Boston harbor, large as it is, would be white with the sails of the great fleet. More than that, many of those articles could never be brought, some because the length of time consumed in wagon transportation would spoil the goods en route, and others because the roughness of the transportation would break and destroy them. Now the speed and facilities of transportation, made so by the skill and labor of the engineer, are such that this city, as well as every other, can appropriate to its uses the products perishable and imperishable of the rest of the earth. Nor are these facilities simply a matter of speed and comfort to passengers. Yet speed and comfort are not to be

forgotten. When you have ridden, as I have, all day in a mountain wagon, a wagon without springs in the body or under the seat, over roads where no attention has been paid to pebbles less than a foot in diameter, especially if you are of the lean and bony kind, not well upholstered, and change at evening to the soft, springy seat and motion of a Pullman coach, you are ready to accept the civil engineer as a public benefactor. But, passing the matter of personal comfort, take, for instance, the stone, iron and timbers which are used in the construction of your large buildings, and without which these buildings could not be constructed. But for this facility of transportation, it would be practically impossible to bring them here, at least in any adequate quantity. You may say that there is an abundance of stone close at hand. Possibly that may be true, and Boston may be favored in the possession of some kinds of building stone; but the marbles and sandstones, which are the facing and beauty of your lofty structures, are not here, and have to be brought, some of them, from long distances. Think of bringing them in wagons! The limited amount that could be brought, and the expense of bringing them, would in effect put a stop to most of the building. What would be the cost of wagoning the needed marble from South Lee or Proctorsville? So as to iron and steel. We see on every street the building beams and framework of steel, and seldom stop to think of the various processes and steps between the iron mine and the building. To move the great masses of iron ore to the furnaces, and, after the melting and manufacturing into ribs and frames of steel, to bring them to the city, involve a transportation which, if wagons alone were used, would practically forbid, on account of the expense, their use in building. And the same of timbers. These which you call the grosser parts of the structure, and yet are the essentials of any successful building, are available for use within the limits of reasonable expense only because of the facilities of transportation furnished by the engineer.

"They point us to the Pyramids and say, 'Behold the mighty works which were done long before the modern facilities of transportation existed,' but think of the enormous consumption of labor and time in their construction, and how few there are of them; while to-day, in our large cities, the sky-scrapers go up in a year or so, and are seen on every hand. And while this is true of these things which form the coarser parts of buildings, it is also and equally true of the decorative articles which are brought from all quarters of the globe, and at a cost which puts them within reach of the ordinary income. And here let me say, in passing, that nearly all the great structures of old are known by the names of the places where they were located, the monarch who ordered them, or the being in whose honor they were built, and not by the names of those by whose brain they were designed or by whose skill they were constructed. It is the Colossus of Rhodes, the Appian Way, the Temple of Solomon and the Temple of Diana. The rule should be otherwise, and every great work should bear the name of him who planned and him who wrought. History is becoming what it ought to be, not a record of wealth, of military glory or inherited position, but rather a record of brains and intellectual achievements.

"Beyond the matter of the construction and adornment of your buildings and homes, the swift and cheap transportation furnished by the engineer puts into your city that great volume of merchandise which adds so much to

the comfort and enjoyment of life. The perishable products of the world are here; tropical fruits and vegetables are in your markets in the winter season, and all parts of the earth pay tribute in the way of supplies for the good living of the people of Boston. In the enormous volume of these supplies and by trade transactions in respect to them great fortunes are made. But the blessing is not mainly in the magnitude of the transactions and the wealth accumulated therefrom, but more in that having been once brought into your midst these articles of comfort and luxury are distributed through the various arteries of trade until even the humblest of your citizens shares in the enjoyment of the products of distant lands. Thus it is that so far as the material things of life are concerned the engineer has made it possible that all parts of the world shall render tribute to this city; and that which is true of Boston is also true of other cities and towns. Each contributes to the prosperity and well-being of the others by furnishing its share of those things which all need.

"But it is not alone in the material side of life that the blessing of the engineer's work is seen. We boast of our wondrous intellectual development, of the great libraries, the millions and millions of books, newspapers and magazines that are scattered daily through the land so that every house has its library and every man is a reader. But do you ever stop to realize that the manufacture of books and magazines and papers at an expense which puts them within the reach of all is owing to the fact that the material which is used in them and in the machinery which is employed in their manufacture is available by reason and only by reason of the cheap transportation furnished by the engineer.

"But I want to go a little farther even than his influence upon intellectual development, and ask what are the relations of his work to the higher life of man? You may say that he deals only with material things; that, while the artist and the architect may express spiritual truths through material forms, the engineer levels all to the basis of utility. I shall not stop to inquire whether usefulness is not in itself one of the highest of virtues, but, accepting the statement that the test and purpose of an engineer's work is utility, I remark that man is a social being; that he reaches his highest stature through the social relations. In solitude his better nature does not grow. Only in society and by society is the higher part of his life developed. He there learns the blessedness of serving others. He is there taught the meaning of 'the brotherhood of man,' and then, and not until then, does he understand 'the fatherhood of God.' The more fully he cultivates his social relations the more like the Master will he become. The soul of a Robinson Crusoe is dwarfed by its isolation. Solitary confinement leads to insanity. He whose horizon is the boundary of a little hamlet is almost sure to develop a little soul. He becomes picayunish. Now, the greater the society into which man enters the more powerful become all the teachings and influences of social relations. Japan, shut up in isolation, continued for centuries in a lower plane of civilization. Fifty years of contact with higher civilization has brought her up and near to it. China, in her seclusion, is way back in the centuries. The breaking down of the barriers and the 'open door' will fill her millions with the possibilities of European civilization. Both as nations and as individuals, life is lifted up by contact with a larger portion of the world. Now, the engineer's work is to improve the highways, and by improving the highways all parts of the world are brought nearer together. Space and time are annihilated. No man is so far away from us as not to be

our neighbor. After all, we find ourselves dwelling in what is but a little world. In the ancient days we are told that men thought to reach the heavens by building a lofty tower of Babel. They did not realize the infinite difference between things material and things spiritual, or understand the profound meaning of the declaration that flesh and blood cannot inherit the kingdom of heaven. Wisely the men of to-day seek rather to remove all the barriers which separate man from man and make plain and easy the approach of each to each. The ancients sought to force an entrance into heaven and failed. We reach a neighbor's hand to all our fellow-men, and thus we shall bring heaven to earth.

" 'Abou Ben Adhem (may his tribe increase!)
Awoke one night from a deep dream of peace,
And saw, within the moonlight in his room,
Making it rich, and like a lily in bloom,
An angel writing in a book of gold:
Exceeding peace had made Ben Adhem bold,
And to the presence in the room he said,
"What writest thou?" The vision raised its head,
And with a look made of all sweet accord,
Answer'd, "The names of those who love the Lord."
"And is mine one?" said Abou. "Nay, not so,"
Replied the angel. Abou spoke more low,
But cheerily still, and said, "I pray thee then,
Write me as one that loves his fellow-men."
The angel wrote and vanished. The next night
It came again with a great wakening light,
And show'd the names whom love of God had bless'd,
And lo! Ben Adhem's name led all the rest.' "

The second speaker was Hon. James E. Cotter, of Boston, who said some complimentary words of the chief guest of the evening, and advanced the expectation that in the future Boston will continue to grow in power and importance, thanks to the civil engineers who will build the great docks and deepen her harbor, so that it may teem with commerce from every part of the world. In closing, Mr. Cotter paid a glowing tribute to Justice Gray, of the United States Supreme Court, formerly from Massachusetts, and voiced the feelings of the gathering in a hope that he may soon return to his post of duty and to remain there for a long time to come.

Prof. Charles W. Rishell, of Boston University, was the next speaker, and told some humorous stories having excellent application to the moment and drew an interesting parallel between the construction work of the engineer and work of the teacher and minister.

The other speakers were Col. W. S. Stanton, Engineer Corps U. S. A.; Mr. J. J. Enneking, a Boston artist; Mr. E. B. Winslow, of Portland, Me.; Mr. F. H. Newell, Hydrographer U. S. Geological Survey; Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies; and Mr. Desmond FitzGerald, a Past President of the American Society of Civil Engineers.

The other guests of the Society were Mr. J. A. Ockerson, of St. Louis, member Mississippi River Commission; Mr. M. Driscoll, president Massachusetts Highway Commission; Mr. F. E. Merrill, president, and Mr. Willard Kent, secretary of the New England Water Works Association; Mr. James

H. Macdonald, Highway Commissioner of Connecticut; Mr. C. M. Ingersoll, Jr., chief engineer, New York, New Haven and Hartford Railroad; Mr. R. A. Shailer, president Boston Tunnel Construction Company; Mr. J. O. Winston, Chicago; Mr. A. S. Tuttle, of Fall River; Mr. B. C. Rich and Mr. G. G. Ledder, of Boston, and Mr. H. H. Clayton, of Milton.

Music was furnished by the Apollo Quartet of Boston.

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Boston, Mass., March 19, 1902.—The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 p.m.; President Lawson B. Bidwell in the chair. Eighty-nine members and visitors present.

The record of the last meeting was read and approved.

The Secretary read the annual report of the Board of Government, which was accepted.

The Secretary also read his annual report, which was accepted.

The Treasurer read his annual report, which was also accepted.

Mr. Holmes presented and read the annual report of the Committee on Excursions, which was accepted.

The Librarian presented and read the annual report of the Committee on the Library, which was accepted.

Mr. FitzGerald presented and read the annual report of the Committee on Quarters, which was accepted.

Mr. FitzGerald then offered the following vote, which was adopted:

Voted: That the Board of Government be authorized to take any action necessary in the matter of renewing the leases or making a new lease with the Tremont Temple Baptist Church, with the New England Water Works Association, and with the Hersey Manufacturing Co., or other desirable lessees, and that the President and Treasurer be authorized to sign such leases on behalf of the Society.

On motion of Professor Swain the following recommendation of the Board of Government was adopted, Voted: That the practice of buying standard engineering books for the Library be commended and that it be continued for the coming year.

On motion of Professor Swain, the recommendation of the Board of Government that a committee of three be appointed to secure advertisements for the Journal, was adopted.

On motion of Mr. Hodgdon, it was voted to refer to the Board of Government, with full powers, the question of appointing the several special committees of the Society and the selection of the members thereof.

Prof. L. P. Kinnicutt then read the paper of the evening entitled, "The Present Status of the Sewage Purification Problem in England," illustrating it with a large number of lantern slides.

A discussion followed, in which Mr. Metcalf and Professors Sedgwick and Kinnicutt took part.

The President, in a brief address, reviewed the events of the past year, speaking substantially as follows:

## ADDRESS OF PRESIDENT L. B. BIDWELL.

In very many respects the past year has been an eventful one. In it our country has developed into a great world power, and an expression of its preference or intention, as shown particularly in China, has not only com-

manded respect but really controlled and modified the demands of the other great powers. Later intimations were given by the other governments that we were the only one that could, with any hope of success, act as a mediator to end the long drawn out South African war. This has been in part due to the training, dash and persistency of our soldiers and sailors, and in a larger part to the statesmanlike course of our President and his advisors, and now an emphatic word from Washington materially affects, and to a considerable extent shapes, the action of every other government. Such power as this should be very carefully exercised with an endeavor always to keep on the side of reason and justice.

During the past year the Chief Executive of our nation was assassinated. All three of our martyred Presidents were men of great ability, Christian men; who planned and worked for the good of our country and for all mankind, and there was never was King or potentate whose taking off was so mourned by their own and other peoples or accorded higher honors than the last, all spontaneously uniting to do him honor. It hardly seems possible this could have happened, and our great government move on without break or hindrance and with no disturbance of that sensitive thing—the general business of our country.

The year has also seen England's greatest Queen pass away, and that nation now has a King, for the first time in about sixty-four years.

As to the part which our five hundred members may have had in causing the growth which has given the nation the standing it now has in the world, I think we are an important factor. Of course we all go to the polls and place our votes for what we think to be the best men, but even good men need material backing. This is largely accomplished by the well being of the individual, the town, city and state, and to this we are constant contributors.

In all great enterprises requiring construction, we are the pioneers, showing what is practical and an approximate cost. Then we take charge and great public and individual works grow from the crude material into creations of utility or beauty. We build the trolley roads which take the people from their very doors and transport them to their places of business for a sum so small that the poorest may ride. The same with our great systems of steam roads, moving the people and produce with wonderful promptness and regularity, which are so reliable that although the very subsistence of the people in our great cities depends almost wholly upon the usual daily movement there is no lack.

We build great reservoirs and supply an abundance of wholesome water, every person using all they desire; also great sewerage systems, making it possible for very thickly settled communities to live in full health and comfort. We erect great buildings, with offices light, well heated and ventilated. We lay out and improve large tracts for park purposes, build boulevards and state highways. We have charge of the building of telegraph and telephone wires, etc. All these things tend to the elevation, growth, compactness or its equivalent in ready transportation and communication, the importance and building up of the nation.

The year has also seen larger accumulations of capital than ever before in the history of our nation. Most of the great steel manufacturing plants are now under the control of one corporation. Our great cross-country lines of railroads are practically under two corporations; these now work in har-

mony, but their fight for control in May last paralyzed the great financial centers, and one day ran up the stock of the Northern Pacific Railroad to $1000 per share.

A great steamship line, the Leyland, consisting of thirty-eight large steamers became allied with another line which aggregates eighty-eight other vessels, making a total tonnage of over 335,000 tons. Also the Northern Pacific Steamship Company, thus giving control of steam lines around the entire globe, and controlling and concentrating enormous manufacturing and transportation interests, reaching out to. such an extent in railroad combinations that the question of governmental control has been revived and may yet lead to a serious movement in that direction.

In a smaller way consolidation of our railroads has been going on for some years, and the tendency still seems that way, but as to government control of them, the opportunity for political jobbery might be a greater menace than great corporation control.

With constant accretions of capital which are greater and more rapid as the country grows older, and its concentration into fewer hands, the distribution not keeping pace with the accumulations, the control of all the necessaries of life will also be by the few, and no legislation will prevent this. Some idea of the capital of one of these can be had from the citation in an application for a charter in New Jersey of the Northern Securities Company for holding the securities of the Great Northern and the Northern Pacific Railroad Companies, which called for a capital of $400,000,000. It is claimed that this consolidation is contrary to the laws of Minnesota, and the State will make every effort to break up the combination, but I think it will not be accomplished, the objection by the State being that all competition is done away with by the two lines which pass through the State.

There is also a rubber trust projected, capital $75,000,000, and a traction combine to control systems of five cities. It has been said that the nineteenth century has been an age of competition and that the twentieth century will be an age of co-operation, and certainly the indications are that this may be a true saying.

In addition to these greater and more prominent combinations, so-called trusts, never before thought of, have been formed or in progress. Among them are the following: A zinc combine with capital of $50,000,000; other steel companies with proposed capital of $250,000,000; National Gas and Coke Co., $5,000,000; Home Bakery Co., $2,500,000; Interstate Independent Telephone and Telegraph Co., $3,000,000; Central Consumers' Co., $2,250,000; National Timber Co., $15,000,000; Gulf Coast Ship Building and Dry Dock Co., $5,000,000; National Lumber Co., $10,000,000, and various others. It is estimated that the industrial corporations completed in 1891, having an authorized capital of $1,000,000 or more, have preferred and common stock to the amount of over two billions of dollars. In the month of November alone the capitalization of corporations in the United States was $587,302,800. There is also a gigantic steel and iron ring project agitated in Russia, with a probable production of 200,000,000 pounds per year, and in Canada a great lumber company which has secured a grant of over 2,500,000 acres of timber lands, and the same people are erecting one of the largest rail mills in Canada, and one of the most complete in the world, almost every thing except driving the engines being done electrically. Probably one of the greatest trusts will be a combination of the salt trusts of this and other countries,

and now nearly consummated, which will control an output of between 5,000,000 and 6,000,000 tons.

This is also the one hundredth anniversary of steam navigation, and in it the largest steamship is being constructed, the "Celtic." The vessel, "Charlotte Dundas" of 1801, was 50 feet long, 18 feet beam and 8 feet deep, with an engine of nominally ten horse power, with a 22-inch cylinder. Compare this with the "Celtic," which has a displacement of 36,000 tons, carrying 3,200 passengers, with engines of 14,000 horse power and a length of 700 feet, 75 feet beam, 49 feet deep, with a tonnage of 20,900 and consumption of coal of 260 tons per day.

This year has also been marked by one of the greatest struggles ever known between labor and capital. The vast combination of capital and the large number of people affected, either directly or indirectly, is without precedent. Although capital (The United States Steel Corporation) was victorious, the loss in earnings has been estimated at $15,000,000 and $10,000,000 on the side of labor (The Amalgamated Association). The number of men thrown out of employment for two or three months was estimated at 50,000. There may be doubt as to there having been so great loss to the corporation, but none as to the great loss to the Association. The reason for the strike did not at first come out very clearly, but it soon appeared that neither wages or hours of labor, which have usually been the causes of grievance leading to strikes, had any part in this late and greatest strike. Certain of the mills taken into the United States Steel Corporation were union and others were non-union. The Association claimed that the union mills were discriminated against in the distribution of material to be worked, while the corporation claimed it was distributed where it best could be manufactured, and the Association endeavored to force the corporation to allow all the mills to be made union mills. As such a concession would have taken from the officers of the corporation the right to handle the property in their charge in what they might conceive to be the most advantageous way, they resisted and the sympathy of the general public was with them, which had a great influence on the situation, and the Association was signally defeated.

Notwithstanding the strike the output for steel for the past year has been largely in excess of that of any previous year and the consumption equally great. The output of the United States Steel Corporation was estimated at 28,000 tons daily. The total output of pig iron in this country the past year is estimated at 16,000,000 gross tons. This is far in excess of any previous year. The same is true of steel rails, with an excess of over 500,000 tons. Also as to shapes and plates which show an excess of probably 250,000 tons. This last item indicates a large consumption in ship building, large buildings, bridging, etc.

The Boston Freight Handlers and sympathetic strike, including approximately 20,000 men, has within the week just ended had its inception and failure, and the men are anxious to return to work under the old conditions. The loss to those who are reinstated is serious when men need every dollar they can earn to support their families, and to such as will not be taken back it must mean very great inconvenience, and in some cases suffering. The whole matter was ill-advised, and this shows again that to succeed the strikers must have good reasons for their action.

In this city of Boston we have this year, after much agitation and some

opposition an elevated railway in operation, to which the only serious objection I have heard of is the noise. I presume as time goes on and the tracks are slightly limbered up this may be somewhat lessened, and do not doubt some way may be found to do away with at least a part. I do not think we should like to be without its convenience even if the noise must continue.

In a political way the most marked change which occurs to me is the overthrow of Tammany in New York after seventeen years' control. I do not think it well for any one party to remain in control for so long a time as abuses and corruption creep in, and a change often brings healthier conditions.

As to engineering projects, projected or agitated, two of the most interesting I think are the Pennsylvania Railroad tunnel between Jersey City and New York, and the Isthmus Canal. Russia is also projecting a great canal from the Baltic to the Black Sea, one of the greatest engineering schemes yet undertaken. A large cantilever bridge is being built across the Ohio River for the Wabash road.

More than fifty years ago I listened to a prophecy of what might be expected in the year 1900, written by Alexander L. Holley. Some of you may remember him. He was an engineer of unusual attainments and had much to do with the introducing of Bessemer steel into this country, and was employed by the Albany and Rensselaer Iron Works. The paper was read in the academy at Stockbridge, where he was then a student, and his prophecy then seemed altogether chimerical, but actually in many ways fell far short of the reality. As I recollect, his highest flight did not at all contemplate the telephone, and that even the features may be distinguished hundreds of miles away, or the wireless system of telegraphy. One of his predictions was that the surgical and healing art would be so far advanced that many members of the body might be, when necessary, replaced. Now certainly, almost any part can be removed and people still live, which approaches this prediction.

It would be a bold man who would dare to outline what would be done fifty years from now in any science. It would not seem unlikely or any more wonderful than what has been accomplished, that Santos Dumont's dirigible air ship, which appears to be as good for navigating the air as any yet made, will before 1950 be replaced by machines which one may enter with confidence for distant transportation, clear of the earth and all its hindrances.

At the conclusion of the President's address Messrs. George T. Sampson and William T. Pierce, the tellers of the election, submitted the result of the letter ballot for officers. In accordance with their report the following officers were declared elected:

President—George A. Kimball.

Vice-President (for two years)—Frederick Brooks.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Alfred D. Flinn.

Director (for two years)—George B. Francis.

Before declaring the meeting adjourned the President introduced the President-elect, Mr. Kimball, who thanked the members for the honor conferred upon him, and pledged his best services to the Society for the coming year.

Adjourned. S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1901-02.

Boston, March 19, 1902.

*To the Members of the Boston Society of Civil Engineers:*

In compliance with the requirements of the Constitution the Board of Government submits its report for the year ending March 19, 1902.

At the last annual meeting the total membership of the Society was 500, of which 492 were members, 2 honorary members and 6 associates. During the past year we have lost 14 members, 11 by resignation and 3 by forfeiture of membership for non-payment of dues.

There have been added to the Society during the year 21 members, making a net gain of 7 members. Our present membership consists of 2 honorary members, 6 associates and 499 members, a total of 507.

Twelve meetings of the Society have been held during the year, ten regular and two special, and the twentieth annual dinner was given at the Hotel Vendome on March 4, 1902. The average attendance at the regular and special meetings was 56, slightly less than for several years past. The largest attendance was 119 and the smallest 18. The attendance at the annual dinner was 151.

The following papers have been read at the several meetings:

March 20, 1901.—Mr. J. A. Ockerson, of St. Louis, "The Mississippi River; Some of its Physical Characteristics and Measures Employed for the Regulation and Control of the Stream." (Illustrated.)

April 17, 1901.—Mr. W. W. Cummings, "Subaqueous Tunnels for Gas Conduits." (Illustrated.) Discussion.

May 15, 1901.—Mr. Frank W. Skinner, "Some Difficult and Curious Foundations." (Illustrated.)

June 19, 1901.—Mr. H. K. Higgins, "Summer Street Viaduct." (Illustrated.) Memoir of John C. Haskell. Mr. Laurence Bradford, "Engineer Corps of the U. S. Army."

September 18, 1901.—Mr. Arthur S. Tuttle, "The Abolition of Grade Crossings on the Providence Division of the New York, New Haven and Hartford Railroad Between Boston and Dedham." (Illustrated.)

October 16, 1901.—Prof. Wm. Carey Poland, "The Development of Artistic Forms in Architecture from Elements of Construction." (Illustration.)

November 20, 1901.—Mr. George T. Sampson, "Railroad Organization." (Illustrated.)

December 11, 1901.—(Special.) Prof. L. J. Johnson, "The Determination of Unit Stresses in the General Case of Flexure."

December 18, 1901.—Mr. F. W. Hodgdon, "Notes in Relation to Docks and other Engineering Structures in Great Britain, France and Belgium." (Illustrated.)

January 22, 1902.—Mr. James H. MacDonald, "From City Streets to Country Road."

February 5, 1902.—(Special.) Mr. J. P. Frizell, "Tidal Scour in Harbors or the Function of Tidal Basins, with Special Reference to the Harbor of Boston." Discussion.

February 19, 1902.—Mr. H. H. Clayton, "Exploration of the Air with Kites." (Illustrated.)

Seven informal meetings have been held in the Society's library during the past year. The subjects discussed at these meetings have been as follows:

December 4, 1901.—Mr. F. A. Barbour, "Some Phases of Sewage Disposal."

January 8, 1902.—Mr. F. J. Warren, "Bituminous Macadam Pavements."

January 15, 1902.—Mr. J. O. DeWolf, "Recent Cotton Mill Work in the South."

January 29, 1902.—Mr. Wm. Parker, "Improvement of B. and A. R. R. Terminals at East Boston."

February 12, 1902.—Mr. F. E. Adams, "Essential Features of Gate Valve Construction."

February 26, 1902.—Mr. B. A. Rich, "Neponset River Bridge at Mattapan."

March 12, 1902.—Mr. H. A. Miller, "Sinking Sheet Piling on the North Dike of the Wachusett Reservoir."

In accordance with the vote of the Society, the Board of Government made application to the General Court for an amendment to the Act of Incorporation of April 24, 1851, increasing the real and personal estate which the Society might hold from $20,000 to $200,000. The amendment was passed, and approved by the Governor, March 12, 1902.

The Board of Government makes the following recommendations:

First. That the Society give authority to the incoming board to take such action as it deems best in the matter of renewing the leases for our present rooms, and that the President and Treasurer of the Society be definitely authorized to sign these leases.

Second. That the practice of buying standard engineering books for the library be commended, and it be recommended that the practice be continued for the coming year.

Third. That an earnest effort be made to secure advertisements for the Journal of the Association of Engineering Societies, and by that means paying a large part, if not the whole, of the assessments levied on the Society for this publication.

In this connection I would say that the Civil Engineers' Club of Cleveland has in this way covered the entire amount of its assessments, and the Western Society of Engineers at the close of the year 1900 had as gross receipts from advertisements in its journal $2,157.50, with a membership about the same as ours and a circulation of 800, while the membership of the Association is now about 1600 and circulation about 200, and the Association covers very much more territory both North and South and East and West, while the Western Society is local.

The Association refunds 90 per cent. of the gross receipts from advertisements to any Society procuring them.

It may be well to appoint a special committee of three for this purpose.

Respectfully submitted for the Board of Government,

Lawson B. Bidwell, *President.*

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Abstract of the Treasurer's and the Secretary's Reports for the Year 1901-02.

CURRENT FUND.

*Receipts:*

| | | |
|---|---|---|
| Dues from new members | $101.50 | |
| Dues for year 1901-02 | 3,389.00 | |
| Dues for year 1902-03 | 43.00 | |
| Sales of Journals, periodicals and from library fines | 20.16 | |
| Rent of rooms | 900.00 | |
| Interest on deposits | 10.43 | |
| Balance on hand March 20, 1901 | 226.83 | |
| | | $4,690.92 |

| | | |
|---|---|---|
| *Receipts* (brought forward) | | $4,690.92 |
| *Expenditures:* | | |
| Rent | $1,650.00 | |
| Association of Engineering Societies | 1,027.50 | |
| Postage, printing and stationery | 494.65 | |
| Secretary's salary | 400.00 | |
| Periodicals and binding | 133.50 | |
| Annual dinner | 122.00 | |
| Incidentals | 114.59 | |
| Stereopticon at meetings | 90.00 | |
| Library supplies and clerical assistance | 25.78 | |
| Lighting rooms | 19.05 | |
| Books | 15.15 | |
| Reporting meetings | 5.00 | |
| | | 4,097.22 |
| Balance on hand | | $593.70 |

PERMANENT FUND.

| | | |
|---|---|---|
| *Receipts:* | | |
| Twenty-one entrance fees | $210.00 | |
| Savings banks | 298.74 | |
| Merchants' Co-operative Bank (one share matured) | 200.20 | |
| Workingmen's Co-operative Bank (shares retired) | 163.84 | |
| Subscription to building fund | 100.00 | |
| Interest | 39.47 | |
| Balance on hand March 20, 1901 | 124.01 | |
| | | $1,136.26 |
| *Expenditures:* | | |
| Dues on shares Workingmen's Co-operative Bank | $302.02 | |
| Dues on shares Merchants' Co-operative Bank | 301.00 | |
| Dues on shares Volunteer Co-operative Bank | 300.00 | |
| Deposit in Provident Institution for Savings | 41.56 | |
| Deposit in Boston Five-cents Savings Bank | 41.14 | |
| Deposit in Eliot Five-cents Savings Bank | 37.17 | |
| Deposit in Warren Institution for Savings | 36.70 | |
| Deposit in Institution for Savings in Roxbury | 36.26 | |
| Deposit in Franklin Savings Bank | 35.91 | |
| | | 1,131.76 |
| Balance on hand | | $4.50 |

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 19, 1902.

| | |
|---|---|
| 25 shares Volunteer Co-operative Bank | $2,397.50 |
| 25 shares Workingmen's Co-operative Bank | 2,289.38 |
| 25 shares Merchants' Co-operative Bank | 1,718.48 |
| Deposited in Provident Institution for Savings | 1,219.25 |
| Deposited in Boston Five-cents Savings Bank | 1,137.13 |
| Deposited in Eliot Five-cents Savings Bank | 1,090.58 |
| Deposited in Warren Institution for Savings | 1,076.61 |
| Deposited in Institution for Savings in Roxbury | 1,063.90 |
| Deposited in Franklin Savings Bank | 1,053.41 |
| One Republican Valley R. R. bond (par value) | 600.00 |
| Cash on deposit in Old Colony Trust Co | 4.50 |
| | $13,650.74 |
| Amount belonging to Permanent Fund March 20, 1901 | 12,787.55 |
| Increase during the year | $863.19 |

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

| | |
|---|---|
| Permanent Fund | $13,650.74 |
| Current Fund | 593.70 |
| | $14,244.44 |
| Total amount March 20, 1901 | 13,014.38 |
| Total increase during the year | $1,230.06 |

REPORT OF COMMITTEE ON EXCURSIONS.

BOSTON, March 19, 1902.

*To the Members of the Boston Society of Civil Engineers:*

Your Excursion Committee hereby presents its annual report for the year 1901-02:

Twelve excursions have been made during the year.

May 4, 1901, to the tunnel being constructed by the Boston Transit Commission at East Boston, and to examine the yacht "Independence" at the Atlantic Works; attendance, 125.

May 15, 1901, to ride upon and inspect a portion of the line of the Boston Elevated Railway; attendance, 229.

June 11, 1901, to the Cambridge Bridge; attendance, 52.

July 24, 1901, to the Wachusett Dam and Reservoir of the Metropolitan Water Works; attendance, 90.

August 17, 1901, to Portland and the works of the Portland Stone Ware Company; attendance, 45.

September 18, 1901, to the yard of the Fore River Ship and Engine Company, at Quincy; attendance, 74.

October 16, 1901, to Charlestown Navy Yard and new dry dock; attendance, 60.

November 20, 1901, to the New York, New Haven and Hartford Railroad car shops at Readville, grade crossings at Blue Hill avenue, Mattapan, and concrete bridge over Neponset River at Mattapan; attendance, 37.

December 18, 1901, to tunnels of the Metropolitan Sewer System at Jamaica Plain, and to the shops of the Buff & Buff Manufacturing Co.: attendance, 40.

January 22, 1902, to visit the Departments of Architecture and Engineering at Harvard University; attendance, 28.

February 19, 1902, to the power station of the Edison Electric Illuminating Company, and to the power station of the Boston Elevated Railway; attendance, 23.

March 19, 1902, to visit the Boston Bridge Works, and also the works and laboratory of Warren Brothers Company, makers of bituminous macadam pavements, both at East Cambridge; attendance, 17.

Total attendance, 820; average, 68.

The total attendance of 820, it appears, exceeds that of any previous year; an attendance of 600 for the year 1898-99 being the next largest.

Together with the duties of conducting the excursions of the year your committee has published twelve numbers of the "Bulletin of New Engineering Work," altogether containing upwards of 50 pages of matter.

The "Bulletins" have been well received, and requests to members and others for information in regard to engineering work under construction

have received immediate and kindly response, for which the committee would take this opportunity to express its appreciation.

There is a cash balance of $14.67 in the hands of the committee.

Respectfully submitted,

John R. Burke, *Chairman,*
J. Albert Holmes, *Sec'y and Treas.,*
Theodore Horton,
Herman K. Higgins,
Henry D. Woods,
*Committee on Excursions.*

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Report of the Library Committee.

Boston, Mass., March 19, 1902.

*To the Members of the Boston Society of Civil Engineers:*

The Committee on the Library makes the following report for the year 1901-02:

Since the last annual meeting the accessions to the library have numbered 232 volumes. Of these, six volumes were text-books purchased by the Society at an expense of $15.15, 62 volumes were books (other than periodicals) received by gift, 52 volumes were public reports received already bound from their original sources, 17 were volumes of public reports, formerly in pamphlet form, assembled and bound by the Society, 57 were volumes of periodicals received by gift, nearly all of which were already bound when received, 19 were volumes of current periodicals received from the publishers by subscription or exchange and bound by the Society, and 19 were transactions or other publications of societies, received by exchange, and, for the most part, bound by our Society. The last accession number is 4762, but, as in former years pamphlets have sometimes been entered in the accessions book, this number is greater than the actual number of volumes in the library.

Notable among the books received by gift are the 49 volumes from the library of the late Charles H. Swan, presented by Mrs. Swan, the 4 volumes of Smiles' "Lives of the Engineers," given by Mr. Bissell, and the *Engineering Index,* 1896-1900, given by Mr. Tinkham. Among the gifts of periodicals should be mentioned Mr. FitzGerald's gift of 7 volumes of (London) *Engineering* (1872-75), and Mr. Herschel's donation of 50 volumes of the *Zeitschrift für Bauwesen,* 1851-1900.

Classified according to the section of the library into which they fall, the accessions for the year are as follows: Section 1, publications of societies, 16 volumes; Section 2, periodicals, 77 volumes; Section 3, municipal reports, 37 volumes; Section 4, state departmental reports, 25 volumes; Section 5, national government reports, 21 volumes; Section 6, congresses, conventions and expositions, 2 volumes; Section 10, text and reference books, etc., 51 volumes; indexes, 3 volumes.

It is estimated that the accessions for the years occupy about 27 linear feet of shelving. The shelf-room now unoccupied (or occupied for merely temporary uses) is roughly estimated at about 45 linear feet. It is, therefore, probable that in less than two years there will be need of additional shelving.

As there was but little demand for the duplicate numbers of *Engineering News, Engineering Record and Railroad Gazette,* and as they occupied valuable space in the library, and could not be stored outside except at a considerable expense, they were offered *gratis* to such members as would take

them away, and by the 20th of January all had been taken. There yet remain a large number of duplicates of other periodicals and of public reports.

One hundred and forty-seven pamphlets, all public reports, formerly in pamphlet cases or loose on the shelves, or in piles unattended to, the accumulations of former years, have been assembled and bound into 17 volumes. About 239 pamphlets, public reports, most of which were formerly loose on the shelves, or accumulated in piles, have been arranged in pamphlet cases and properly labeled. Some of the latter have not yet been catalogued. There remain, loose on the shelves, or accumulated in piles, about 270 pamphlets, which ought to be bound or arranged in pamphlet cases for the sake of preserving them.

Of the amount voted by the Society to be spent for standard engineering books, but a small portion was used. The Society received by gift a large number of standard books, and the Librarian did not have time to select books for purchase. We recommend that the policy of purchasing standard engineering books, both current publications and older books, be continued.

Respectfully submitted,

Louis F. Cutter,
Frederic H. Fay,
Alfred D. Flinn,
Henry F. Bryant,
*Committee on the Library.*

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## Engineers' Club of Minneapolis.

153d Meeting, January 27, 1902.—Held at their rooms in the County Commissioners' office in the Court House; President Hoag in the chair. Fifteen members and six visitors present.

After the usual order of business was disposed of the following papers were read and discussed: "Asphalt and Brick Pavements," by George W. Sublette, City Engineer; "Sidewalk Construction," by W. F. Dealing, City Sidewalk Engineer.

Albert Graber, *Secretary pro tem.*

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154th Meeting, February 17, 1902.—Held at their rooms in the Court House; President Hoag in the chair. Twenty-three members and twenty visitors present.

The general subject of the meeting, as announced, was "A Consideration of the Water Supply of Minneapolis." The chief paper of the evening was by Dr. Leo M. Crafts on "The Sanitary Bearing of the Subject and the use of Mille Lacs Lake." A metropolitan water commission to gather data on the subject was favored.

City Engineer Sublette and J. F. Fanning discussed the engineering features of the work, and the present supply of water to the city. Professor Hoag referred to the possible use of springs in the St. Croix Valley, and of an artesian well supply. W. W. Redfield favored the use of water from Lake Superior, 200 miles distant, for Minneapolis, St. Paul and other cities of the State.

Edward P. Burch, *Secretary.*

155TH MEETING, MARCH 24, 1902.—Held at the Court House; Vice-President Avery in the chair. Eighteen members and twenty-six visitors present.

The general subject of discussion was "The New Chamber of Commerce Building."

Mr. C. L. Pillsbury read a paper on "The Mechanical and Electrical Features of the Building." Mr. W. W. Ensign discussed "The Heating and Ventilating." Mr. William Robertson discussed "The Elevators and Engines."

The following members have been elected and have qualified as active members of the Club: D. C. Washburn, transitman, City Engineer's Office, Minneapolis; S. M. White, assistant engineer, Great Northern Railway, West Superior, Wis.; James Gillman, chief draftsman, American Bridge Co., Minneapolis; W. F. Dealing, city sidewalk engineer, Minneapolis; Edwin S. Frazer, chief draftsman, Minneapolis and St. Louis Railway, Minneapolis; Henry D. Lackore, meter inspector, Minneapolis Gen. Elec. Co., Minneapolis; C. A. P. Turner, civil engineer, Phœnix Building, Minneapolis; K. Oustad, city bridge engineer, Minneapolis; B. Waller, superintendent of equipment, N. W. Tel. Exchange Co., Minneapolis; W. E. King, draftsman, American Bridge Co., Minneapolis; Fred H. Bass, student, State University, Minneapolis; J. G. Robertson, mechanical engineer, St. Paul, Minn.; E. H. Tromanhauser, elevator builder, Minneapolis; E. F. Pabody, Jr., draftsman, American Bridge Co., Minneapolis.

The following members have resigned: Edwin R. Williams, Minneapolis, Minn.; Harry E. Smith, Brooklyn, N. Y.

Net gain in membership, twelve.

EDWARD P. BURCH, *Secretary.*

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## Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., FEBRUARY 10, 1902.—Regular meeting of the Civil Engineers' Society of St. Paul, was held in the Society rooms, President Münster in the chair. After usual routine business was transacted, President Münster presented a paper upon "Train Velocities and Grade Reductions," thoroughly original in its nature and which the members requested be published. In addition to presenting the formula, Mr. Münster presented the curve, up to and including the speed of 35 miles per hour.

Further routine business was transacted and the meeting adjourned.

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ST. PAUL, MINN., MARCH 10, 1902.—Regular meeting of the Civil Engineers' Society was held in the Society rooms March 10th, President Münster in the chair. After the usual routine business was transacted, Mr. C. A. Winslow presented the maps and explained the flowage rights and water supply of the city of St. Paul, in which all members present took part in discussion.

It is intended that the Society shall in a body visit the various supplies during the coming season, at which time it is desired that all members and their visiting friends may be present.

It is intended to extend the character and scope of the library of the Society, to which end the interest of all members and their friends are invited.

G. S. EDMONDSTONE, *Secretary.*

## Technical Society of the Pacific Coast.

Regular Meeting, March 7, 1902.—Called to order at 8.30 P.M. by President Henny.

The minutes of the last regular meeting were read and approved.

An application for membership was read from Mr. Milton Bulkley, of the firm of Henshaw, Bulkley & Co., of San Francisco, proposed by Professor F. G. Hesse, S. G. Hindes and Otto von Geldern.

The following gentlemen were declared duly elected members of the Society after a count of ballots: J. G. McMillan, County Surveyor, of San Jose, Cal.; Thos. Smith, draftsman, of San Francisco.

Mr. R. G. Paddock read a paper entitled "Fluid Fuel; its Past and Present Practices and its Future Possibilities," which was discussed at length.

Mr. H. D. Connick stated to the Society certain views, suggesting the arrangement of a general meeting of engineers, irrespective of Society affiliations, to take place at some time in the near future, for the purpose of bringing together the many scattered elements of the profession; to read and discuss technical papers, and to visit engineering works in the vicinity; the object being to awaken an interest in the matter of writing and discussing technical papers, and to make this a more public gathering than that of the ordinary Society meeting.

This subject was discussed at some length, it being the general opinion that the proposition is worthy of entertaining, and that a committee should be appointed to formulate some plan and lay it before the Society at the next regular meeting of April.

This was made as a motion and carried, whereupon the Chair appointed the following members to act as such committee and to report to the Society in due time: H. D. Connick, C. E. Grunsky, N. B. Livermore, L. E. Hunt and C. B. Wing.

The Secretary was instructed to notify these members.

A vote of thanks was passed for Mr. Paddock in appreciation of his valuable paper on "Fluid Fuel," which had been the instructive subject for discussion of the evening.

Meeting adjourned. Otto von Geldern, *Secretary.*

## Engineers' Society of Western New York.

Regular Meeting, March 4, 1902.—Meeting called to order by the President at 8.30 P.M. The following members were present: Messrs. Haven, Tutton, Norton, Roberts, Kielland, Babcock, Bassett and Thorne. The minutes of the last regular meeting were read and approved. The President reported that the Executive Board had received, approved and referred to the Society the application of Augustus T. Throop as member. This was read by the Society, approved by the meeting and ordered to letter ballot. The President announced that the Society had elected as associate, Mr. Louis H. Gipp.

Votes of thanks were extended to Mr. Charles H. Tutton (member of the Society) for his gift of a volume of the *Engineering Record,* and to Mr. George A. Ricker (Past President of the Society) for his gift of several

volumes of each of the following named papers: *The Engineering News, The Engineering Record, The Electrical World, The Street Railway Journal* and several other valuable periodicals. The President called attention to the condition of the library, stating that the Society was very much in need of money to bind the various serial magazines and newspapers now tied up in bundles. He said that including the gifts of Messrs. Ricker and Tutton, the Society has on hand and ready to be bound, thirty volumes of magazines, over fifty full volumes of engineering periodicals and enough for ten full volumes of miscellaneous engineering pamphlets. He said that the Society owned the indexes to current literature from 1883 to 1901, and that many of the articles referred to in the indexes were in these unbound volumes which, in their present condition, were of but little if any value to the members of the Society. To enable the Treasurer to pay for the binding done in 1901, and to bind the volumes above mentioned, the Society needs at once the sum of one hundred and fifty dollars, and fifty dollars should be placed every year at the disposal of the Librarian for subscriptions and for binding. The President also said that at the rate the publications are increasing, it will soon be necessary to secure another book-case.

Meeting adjourned at 9.30 P.M.

GEORGE T. ROBERTS, *Secretary.*

# Association of Engineering Societies.

Vol. XXVIII. **APRIL, 1902.** No. 4.

## PROCEEDINGS.

### Technical Society of the Pacific Coast.

Regular Meeting, April 4, 1902.—Called to order at 8.30 p.m. by Past-President Grunsky.

The minutes of the last meeting were read and approved.

Mr. Milton Bulkley, of San Francisco, was admitted to membership after a count of ballots.

The following names were proposed for members: Fred A. Temple, civil engineer, proposed by C. E. Grunsky, H. D. Connick and F. C. Herrmann; John Otis Burrage, civil engineer and draftsman, proposed by C. E. Grunsky, H. D. Connick and F. C. Herrmann; James Michael Owens, draftsman, proposed by C. E. Grunsky, H. D. Connick and F. C. Herrmann; Wm. C. Pidge, surveyor and civil engineer, proposed by C. E. Grunsky, H. D. Connick and F. C. Herrmann.

Mr. H. D. Connick, as chairman of the Committee on Holding an Engineers' Convention in San Francisco, reported in detail as to the proposed plan. outlining a set program for two days and evenings, including a reception, the reading of technical papers and excursions *in corpore* to prominent engineering works of interest in the vicinity.

The report was received and discussed. It was ordered upon motion that the committee be retained, and that it circulate a notice to all members, apprising them in detail of the plan and program, and calling for voluntary contributions, to cover the expenditures, which the committee had estimated would be about $250.

It was suggested by Colonel Wallis that the local members of the American Society of Mechanical Engineers be asked to participate, and likewise was it asked by Mr. H. I. Randall that a similar courtesy be extended to those of the Society of Electrical Engineers.

The Secretary thereupon stated the intention of the committee to be to make the convention a most general one, open to all engineers on the coast, irrespective of society affiliations, and that the Technical Society would merely control the arrangements, having taken the initiative in this movement.

The committee was instructed to extend invitations to the President's and the engineering faculties of the two universities. Also to invite the members of the Chapter of Architects, and to request one of the architects to submit

a paper on the "Construction of Tall Buildings." Mr. Wright was instructed to take this matter in hand and to choose some one willing to prepare and read such a paper during the convention.

The committee will proceed with the duties of detailing the program, and of communicating with the members of the Society, and it will report to the members at the regular meeting in May, so that the final arrangements may be made for the convention, which is to be held in May or June.

No further business appearing, the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

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## Boston Society of Civil Engineers.

BOSTON, APRIL 16, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 P.M., President George A. Kimball in the chair; ninety-five members and visitors present.

The record of the annual meeting of March 19th was read and approved.

Mr. Charles F. Prichard was elected a member of the Society.

The Secretary reported for the Board of Government that it had appointed the following special committees of the Society:

Committee on Excursions—J. Albert Holmes, Henry D. Woods, Herman K. Higgins, DeWitt C. Webb and Dwight L. Hubbard.

Committee on the Library—Alfred D. Flinn, Frank P. McKibben, Henry F. Bryant, Frederic I. Winslow and Frank H. Carter.

Committee on Quarters—Desmond FitzGerald, Edward W. Howe, C. Frank Allen, Ernest W. Bowditch and Hezekiah Bissell.

Committee on Advertisements—Edward W. Howe, Albert S. Glover and Fred V. Fuller.

Members of Board of Managers, Association of Engineering Societies—S. Everett Tinkham, John R. Freeman, Henry Manley, Frederick Brooks and Dexter Brackett.

Mr. Desmond FitzGerald was then presented and gave an exceedingly interesting and instructive talk on the Chicago Drainage Canal. The talk was illustrated by a large number of lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

# Association of Engineering Societies.

Vol. XXVIII. **MAY, 1902.** No. 5.

## PROCEEDINGS.

### Engineers' Club of St. Louis.

540th Meeting, St. Louis, March 5, 1902.—Held at the Club rooms in the Holland Annex, 709 Pine street. At this meeting the St. Louis Chapter of the American Institute of Architects and the St. Louis Architectural Club united with the Engineers' Club in a smoker and housewarming to celebrate the opening of the new quarters which have been jointly fitted up by the three associated clubs.

About one hundred and fifty members and guests were present.

The meeting was called to order by Prof. J. L. Van Ornum, chairman of the Governing Board of the Associated Technical Clubs. Professor Van Ornum spoke of the work of the board and congratulated the clubs in the successful accomplishment of a long desired object. He hoped that the more intimate association of the architects and the engineers in the new quarters would result in a closer union and a better understanding between the professions.

The Chairman then called upon Mr. W. L. Eames, President of the St. Louis Chapter of the American Institute of Architects; Mr. J. H. Kinealy, President of the Engineers' Club; and Mr. G. F. A. Brueggeman, President of the St. Louis Architectural Club. Each of the presidents gave a short historical sketch of his Club and of the steps leading to the association of the three clubs.

The Chairman then called upon Prof. W. S. Chaplin, Chancellor of Washington University; Prof. C. M. Woodward, Dean of the School of Engineering of Washington University; Mr. Robert Moore, President American Society of Civil Engineers; Mr. B. H. Colby, Past-President of the Engineers' Club; Mr. William B. Ittner, Commissioner of School Buildings of the Board of Education, and Mr. Cope, of Philadelphia. The hope was expressed that the associated clubs might ultimately include all scientific societies in the city, and that they might be housed in a fire-proof building, which would afford a place for social gatherings and professional meetings as well as a safe keeping for their libraries and archives.

The meeting then adjourned to the adjoining room, where refreshments were served.

D. W. Roper, *Secretary.*

541st Meeting, March 19, 1902.—Held at rooms of Club at 8 p.m.; President Kinealy in the chair. Present thirty-six members and nine visitors.

Minutes of 539th and 540th meetings were read and approved.

Minutes of 324th and 325th meetings of Executive Committee were read.

Minutes of the 3d, 4th and 5th meetings of Governing Board were read.

The applications of Messrs. Phil J. Markmann, Frederick Thomas Llewellyn, William H. Getz, C. D. Allan and Walter E. Winn were read and referred to the Executive Committee.

Messrs. Henry Rustin and Robert E. Einstein were elected to membership in the Club.

Mr. Fay reported, for the committee appointed to move the effects of the Club from 1600 Locust Street, that they had moved everything on the list furnished them by the members of the Governing Board. He also reported that Captain Boyce, of the Historical Society, had called on him and claimed a number of chairs which had been moved. On motion of Mr. Fay, duly seconded, it was ordered that the President appoint a committee of three of the older members to confer with the Historical Society and adjust the matter. The President appointed Messrs. Bryan, Colby and Ockerson on this committee.

The Secretary then read the amendments to the By-laws, which were proposed at the meeting of February 19th, and which had been made a special order of business for this meeting. Mr. Wall offered a set of amendments which he proposed to substitute for those previously submitted. On motion of Mr. Ockerson, duly seconded, it was voted that the Secretary be instructed to print and send to each member a copy of both sets of amendments, together with any other that might be submitted at this meeting. Messrs. R. H. Phillips and G. I. Bouton also presented amendments to be printed in accordance with this motion.

The Secretary read a communication from the Kings Highway Boulevard Improvement Association. No action was taken on the communication.

The President then introduced Mr. R. D. O. Johnson, who addressed the Club on the subject "Lead Mining in Southeastern Missouri." Mr. Johnson described the geological formations in which the various deposits were found; the various forms of deposits, and their distribution. The several schemes of mining were described.

The paper was discussed by Messrs. Wheeler and Bilharz.

A vote of thanks was tendered to Mr. Johnson for his paper.

The meeting adjourned to the adjoining rooms to partake of a light lunch provided by the Entertainment Committee.

D. W. Roper, *Secretary.*

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542d Meeting, St. Louis, April 2, 1902.—Held at the rooms of the Club at 8 p.m.; President Kinealy in the chair. Present, twenty-seven members and six visitors.

The minutes of the 541st meeting were read and approved.

The minutes of the 327th meeting of the Executive Committee were read.

The resignation of Mr. G. I. Bouton, as Treasurer, was presented to the Club.

The Secretary read an invitation from the Missouri Historical Society to the members of the Engineers' Club for the loan exhibition at the Society's rooms.

The St. Louis Architectural Club invited the members to their third annual exhibition at the Museum of Fine Arts.

The application of Mr. J. J. Kessler, Jr., was read and referred to the Executive Committee.

Messrs. P. J. Markmann, F. T. Llewellyn, W. H. Getz, C. D. Allan and W. E. Winn were elected to membership.

The Librarian reported that Professor Van Ornum had presented to the Club the annual report for 1901 of General Ludlow, Military Governor of Havana. On motion of the Librarian it was accepted with the thanks of the Club.

The Club then proceeded to elect a Treasurer to fill the vacancy caused by the resignation of Mr. G. I. Bouton. Messrs. Perkins, Wall, Bryan and Hunicke were placed in nomination. The first ballot resulting in no election, the latter two names were, on motion, dropped from the list of candidates. On the second ballot Mr. Wall was elected.

The matter of the amendments to the By-laws was then taken up by the Club and discussed at some length.

As no single set of amendments were satisfactory to the Club, it was, upon motion, duly seconded, ordered that the matter be referred to a special committee consisting of those who had drawn up the amendments submitted, viz: Messrs. Russell, Flad, Colby, Wall, R. H. Phillips and G. I. Bouton, and report at the next meeting a new set of amendments. As the result of several additional motions the special committee was instructed to include in the amendments to be submitted by them:

(1) The feature of a nominating committee.

(2) Provision that no member can serve on the Nominating Committee more than once in two years.

(3) That the Nominating Committee shall submit but one candidate for each office.

(4) A plurality of votes cast shall be sufficient to elect.

The President then introduced Mr. H. H. Humphrey, who read a paper entitled "Notes on the Use of Beaumont Oil as Fuel." The oil district is only a few hundred acres in extent and the wells are thickly crowded. The capacity of the wells range from 10,000 to 80,000 barrels per day, and the pressure does not seem to be affected by additional wells. If all the wells were allowed to flow at once and the pressure was not diminished, the total flow would be about seven million barrels per day. While the oil is of great importance to the Southwest, where coal is scarce and of inferior quality, its use in more remote districts appears to be limited by transportation rates and facilities. The price at St. Louis was recently quoted at $1.14 per barrel of which nine cents was for the oil and $1.05 for the freight. The oil is a smokeless fuel when properly burned. The steam jets used in connection with the burners consume from three per cent. to thirteen per cent. of the total steam generated. The present insurance rules require a minimum distance of fifty feet between an underground tank and the nearest building. Its use in cities would therefore require considerable expense for storage space.

In one plant in Texas for which estimates were made it required oil valued at $1.39 to equal a ton of coal at $2.50. At St. Louis the price will have to be reduced to about sixty cents per barrel in order to compete with coal. Some bids were received for the oil-burning equipment of two 100 horse-power boilers. The prices ranged from $704 to $1525. The price of

oil, f. o. b. Dallas, ranged from forty-five cents to fifty cents per barrel on a year's contract, and the price increased with the length of term of the contract.

The best tests show an evaporation of about fifteen pounds of water to one of oil.

The cost of the average well as reported by a competent authority to the Bureau of Statistics at Washington, D. C., was about $12,000.

The paper was discussed by Messrs. Flad, Bausch, Perkins, Johnson and others.

The Club then adjourned to an adjoining room, where a light lunch had been provided by the Entertainment Committee.

D. W. Roper, *Secretary.*

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543d Meeting, St. Louis, April 16, 1902.—Held at the rooms of the Club, Holland Annex Building, at 8 p.m.; President Kinealy in the chair. Present, thirty-three members, six visitors.

The minutes of the 542d meeting were read and approved.

The minutes of the 328th meeting of the Executive Committee were read.

A communication from the Pall Mall Club, of London, England, was read.

The application of Mr. Guy Tyler Norton was read and referred to the Executive Committee. Mr. J. J. Kessler, Jr., was elected to membership.

Mr. W. H. Bryan, of the committee appointed to interview the Missouri Historical Society regarding chairs submitted a report.

The President requested the Committee on Chairs and the Moving Committee to endeavor to arrange a settlement with the Missouri Historical Society in accordance with the report.

Mr. Russell, of the special committee appointed to draw up a new set of amendments to the By-laws, submitted a report, which was, upon motion, received and the committee discharged.

Mr. R. H. Phillips, a member of the committee, reported that a majority of the committee had objected to some of the instructions given them by the Club at its previous meeting and moved to amend certain sections of the By-laws in accordance with the views of a majority of the committee. The motion was, however, lost. After some further discussion the report of the committee was adopted.

The President then introduced Mr. R. H. Klauder, who presented a paper, entitled "Present American Storage Battery Practice."

While America was not first in the adoption of the electrical accumulator it has surpassed European countries in successful methods of its application. Fundamentally the necessity for the use of a storage battery depends on the fact that the loads on generating stations vary, resulting in requiring investment in machinery which may have the opportunity, during a short portion of its life, of earning a return. The variation in the load also results in low economy. The ideal condition for a station would be to have generating machinery run through the entire twenty-four hours at a uniform load. This is not possible as a battery large enough for this costs more than the saving to be obtained from it. All that it is practicable to do, therefore, is to install a battery large enough to take care of the sharpest part of the peak and to carry the entire load during minimum hours. In railway work a storage battery

may be applied either as an auxiliary to the generating machinery or the distributing system. In the generating stations it increases the economy of the engines, reduces the depreciation and repairs on the machinery and increases the capacity of the station. When applied to a direct current feeder it increases its capacity, reduces the loss in the copper, reduces the fixed charges per kilowatt hour delivered and maintains the pressure. In rotary substations the equipment, including batteries, costs no more than that without them and is much more economical. In isolated plants a battery permits electric elevators to be supplied from the same generators as furnish light, besides giving current at all hours of the twenty-four without the necessity of running the machinery.

The paper was illustrated by a number of lantern slides showing completed installations and curves showing the results obtained by the use of batteries.

The paper was discussed by Messrs. Reber, Zeller, Langsdorf, Roper and others.

The meeting then adjourned to the adjoining room, where a light lunch had been provided by the Entertainment Committee.

D. W. Roper, *Secretary.*

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544th Meeting, St. Louis, May 7, 1902.—Held at the rooms of the Club, Holland Annex Building, at 8 p.m.; with President Kinealy in the chair. Present, twenty-six members and fifteen visitors.

The minutes of the 543d meeting were read and approved.

The minutes of the 328th and 329th meetings of the Executive Committee were read. The application of Mr. L. F. Goodale was read and referred to the Executive Committee.

Mr. G. T. Norton was elected to membership.

The President then introduced Mr. A. S. Langsdorf, who read a paper entitled "Commercial Testing of Electrical Machinery." He described the regular and special commercial tests made in the factory on the dynamos, motors, transformers, converters, etc., before shipment. The regular tests included the insulation and load tests. The special tests were generally made to determine the efficiency or other special features which may have been guaranteed in the contracts. Other tests are always made on the first machine of a new design in order to determine the electrical constants and to check the calculations of the engineering department.

In testing small machines the current generated is consumed in resistances, generally water rheostats. For large machines the power required for testing in this manner would be very excessive and some modification of the stray power method is used for economical reasons.

The applications of this method to various kinds of apparatus were described.

The paper was illustrated with a number of lantern slides and drawings of the various methods of testing described.

The paper was discussed by Messrs. Barry and Roper.

On motion the meeting adjourned to the adjoining room, where a light lunch was served under the direction of the Entertainment Committee.

D. W. Roper, *Secretary.*

## Detroit Engineering Society.

DETROIT, MICH., APRIL 25, 1902.—The eighth annual meeting of the Detroit Engineering Society was held at the Hotel St. Clair.

The reports of the Secretary and Treasurer were read and adopted.

The Secretary reported twenty-one members added to the Society during the year, and ten resignations received, making the net membership one hundred and sixteen at the close of the year.

The Treasurer presented a very satisfactory financial report as follows:

RECEIPTS.

| | | |
|---|---|---|
| Cash on hand at beginning of year | $223.40 | |
| Receipts from dues, etc | 510.50 | |
| | | $733.90 |

EXPENDITURES.

| | | |
|---|---|---|
| Banquet | $130.95 | |
| Refreshments "Ladies' Night" | 69.00 | |
| Publication | 221.50 | |
| Secretary's salary | 100.00 | |
| Incidental and office expenses | 88.67 | |
| Cash on hand | 123.78 | |
| | | $733.90 |

Major W. H. Bixby and Mr. H. B. Gunnison were elected to membership in the Society.

The Society then proceeded to the election of officers for the ensuing year, with the following result:

President—E. E. Haskell.

First Vice-President—F. C. McMath.

Second Vice-President—T. H. Hinchman, Jr.

Secretary and Treasurer—Clarence W. Hubbell.

The meeting adjourned at 9.05 P.M. to the annual banquet, at which about fifty members were present.

The retiring President, Willard Pope, acting as toastmaster, introduced the following list of toasts:

"Reminiscences," W. S. Russell.

"The Engineer as a Constructor," Geo. H. Kimball.

"The Artistic and the Practical," Prof. H. C. Sadler.

"The Unharnessed Horses," Prof. C. L. Weil.

"The Fourth Dimension," W. S. Conant.

"The Engineer as a Referee," Prof. M. E. Cooley.

"The Known Quantity," Prof. Gardner S. Williams.

T. H. HINCHMAN, JR., *Secretary.*

## Engineers' Club of Minneapolis.

156TH MEETING, MINNEAPOLIS, MINN., APRIL 28, 1902.—Held at their rooms at the Court House, President Hoag in the chair; forty members and visitors present.

After the usual order of business was disposed of Mr. W. D. Wheeler, division engineer, Minneapolis and St. Louis Railroad, presented a paper on

"Railway Maintenance of Way," discussing numerous phases of present practice on grades, alignment, bridges, depot grounds, etc.

Mr. F. E. Rice, assistant engineer of bridges, Chicago, Milwaukee and St. Paul Railway, followed with a paper on "The New Short Line Bridge Near Minneapolis," a most interesting paper, well illustrated by thirty-five stereopticon views.

ALBERT GRABER, *Secretary pro tem.*

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157TH MEETING, MINNEAPOLIS, MINN., MAY 19, 1902.—The regular meeting of the Club was held in the Court House, President Hoag in the chair. The usual order of business was disposed of.

Mr. George W. Cooley, county surveyor, President State Good Roads Association, presented a paper on "Good Roads." The paper was followed by a discussion of the subject by George W. Sublette, city engineer, and Prof. Wm. R. Hoag. Much interest was taken in the whole matter by the members.

The following members have been elected and have qualified as active members of the Club:

Adolf Wagner, superintendent New Ulm Electric Company, New Ulm, Minn.

J. C. Holland, civil engineering student, University of Minnesota.

W. W. Ensign, heating and ventilating engineer, Minneapolis.

A. J. Archambro, heating engineer, Minneapolis.

M. T. Patterson, draftsman, 1532 North Twelfth street, Philadelphia, Pa.

Edwin M. Grime, assistant engineer, Chicago Great Western Railway, St. Paul, Minn.

Philip Bellin, draftsman, American Bridge Company, Minneapolis.

F. E. King, assistant engineer, Chicago, Milwaukee and St. Paul Railway, Mason City, Iowa.

Total gain in membership, eight. EDWARD P. BURCH, *Secretary.*

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## Technical Society of the Pacific Coast.

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REGULAR MEETING, MAY 2, 1902.—Called to order at 8.30 P.M. by Past-President Grunsky.

The minutes of the last regular meeting were read and approved.

Upon a count of ballots the following four names were elected to resident membership: John O. Burrage, draftsman, City Engineer's Office; James M. Owens, draftsman, City Engineer's Office; William C. Pidge, surveyor, City Engineer's Office; Fred. A. Temple, City Engineer's Office.

Mr. H. D. Connick, as chairman of the Committee on Engineers' Convention, reported that progress had been made in the matter and that the committee had oulined a program, which he submitted, and which in its main features might stand or be modified to suit any condition that may arise.

PROGRAM.

A convention of the Technical Society of the Pacific Coast to be held in San Francisco on May 29, 30 and 31, 1902.

Local members of the American Society of Civil Engineers, of the American Society of Mechanical Engineers, of the Chapter of Architects

and of the American Institute of Electrical Engineers and Civil Engineers within convenient reach of this city are to be invited to active participation in this convention, to attend meetings, to take part in the discussions and to join in the excursions.

Expenses of the reception on the first day and of the excursion on the second day are estimated not to exceed $250. Active participants are requested to subscribe at least $3 to the expense fund. The expense connected with the excursion to Mare Island is estimated not to exceed $1.50 per person, including luncheon. This amount will become payable to the Committee of Arrangements and will be collected by the sale of tickets. The expenses connected with the inspection of the fortification works at the Presidio will probably not exceed cost of transportation, preliminarily estimated at fifty cents each.

It may be necessary, on May 30th, to restrict the number of passengers on the steamer to participants and their families. This will be determined on the basis of the replies received.

Members are invited to active participation in this convention and are requested to reply at once by postal card.

So far as can at present be determined the program will be as follows:

May 29th, Evening, 8.30 o'clock.—Informal reception of participants in the convention and ladies at Century Club Hall, 1215 Sutter street, where addresses will be made by President D. C. Henny and Mr. G. W. Dickie, after which there will be music and refreshments.

May 30th, Morning Session, 9 o'clock.—Convention will assemble at the Academy of Sciences Hall, where a paper will be read by Mr. Hindes, on the "Hunter's Point Dry Dock," and discussed; after which a visit, by boat, to the dock will be made, where luncheon will be served and the dock inspected. Returning, the party will land at the Union Iron Works wharf, whence as many as possible of the following points will be visited: Union Iron Works, Risdon Iron Works, Independent Electric Light and Power Company's plant, Independent Gas Company's plant, Western Sugar Refinery, Santa Fé Grading Camp, Bryant Street Power House of the Market Street Railroad Company and Army Street Sewer.

Evening Session, 8.30 o'clock.—Convention will reassemble at the Academy of Sciences Hall where Mr. Burr Bassell's paper on the "Tabeaut Dam of the Standard Electric Company," will be presented and discussed, to be illustrated with lantern slides showing its construction at various stages.

The discussion of Mr. Hindes' paper on the "Hunter's Point Dry Dock" will be reopened.

First, May 31st, one of the following programs will be carried out. Morning Session, 9 o'clock.—The convention will assemble at the Academy of Sciences Hall, from which the members will visit the Navy Yard at Mare Island. The trip will be made by boat, lunch being served *en route.*

Evening Session, 8.30 o'clock.—The convention will reassemble at Academy of Sciences Hall. A paper on "Skeleton Steel Frame Construction" will be read by Mr. R. W. Hart, and discussed.

Second, Alternative Program for May 31st.—The convention will assemble at the Academy of Sciences Hall, at 9 o'clock, and a paper on "Skeleton Steel Frame Construction" will be read by Mr. R. W. Hart, and discussed, after which a visit will be made to the following steel frame buildings: Flood Building, Crocker Hotel and Mutual Savings Building.

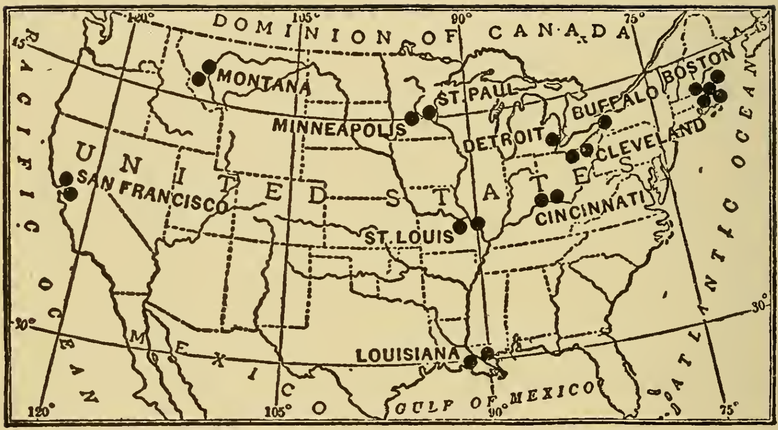
During the afternoon, the members of the convention will visit and inspect at close view the fortification works of the United States Government at the Presidio.

Evening Session, 8.30 o'clock.—The convention will reassemble at Academy of Sciences Hall and continue the discussion of the technical subjects brought up during the convention.

The Society adopted the report and instructed the committee to proceed. It was ordered that more definite invitations be printed and that a detailed program be circulated to all those who had signified their willingness to attend the convention.

All arrangements were left in the hands of the committee with full power to proceed, and it was agreed that this program here outlined should hold good, though it becomes necessary to postpone the convention to some later time in autumn.

Meeting adjourned. OTTO VON GELDERN, *Secretary.*


DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
ST. PAUL
MINNEAPOLIS
DETROIT
BUFFALO
BOSTON
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
45°
30°

# Association of Engineering Societies.

Vol. XXVIII. **JUNE, 1902.** No. 6

## PROCEEDINGS.

### Boston Society of Civil Engineers.

Boston, May 14, 1902.—A special meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 P.M., President George A. Kimball in the chair; seventy-six members and visitors present.

On motion of Mr. Brooks, it was voted to omit the regular meeting of May 21st.

On motion, the thanks of the Society were voted to the United Traction and Electric Company, of Providence, and to Messrs. Horton and Hemenway, for courtesies shown the Society on the occasion of the trip to Providence this afternoon.

The first paper of the evening was read by Mr. George B. Francis, entitled "Light Mountain Railways." The paper was discussed briefly by Messrs. Henry Manley and G. R. Hardy.

Mr. Francis then read his second paper, entitled "The Street Railway System of Providence and Vicinity." A general discussion followed.

Mr. Arthur L. Plimpton gave an interesting account of "Street Railway Track Construction in City Streets," and Mr. Henry Manley followed, speaking of the "Relation of Street Railway Tracks to the Paving of City Streets."

Mr. Gilbert Hodges spoke of "Track and Overhead Construction on Suburban and Interurban Roads," and Mr. Harold Parker spoke briefly of the "Relation of Street Railways to State Roads."

Mr. C. S. Sergeant, Vice-President of the Boston Elevated Railway, closed the discussion of the evening, speaking particularly of the changes which the introduction of interurban cars on city streets would require in track construction.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, June 18, 1902.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 P.M., President Geo. A. Kimball in the chair; thirty-two members and visitors present.

The record of the regular meeting of April 16th and that of the special meeting of May 14th were read and approved.

Messrs. W. Dabney Hunter and Robert W. Pond were elected members of the Society.

The Secretary read a communication from the Secretary of the American Society of Mechanical Engineers transmitting the following resolution passed by that Society at its Boston meeting:

"The American Society of Mechanical Engineers would ask that Mr. George A. Kimball, President of the Boston Society of Civil Engineers, would accept from the Society a sincere expression of its thanks for the cordial wording of his address of welcome.

"While it is true that year by year the profession of engineering is specializing, it is none the less true that at the bottom, all engineering is one, and we ask that Mr. Kimball and his Society will rest assured that in our recognizing the achievements with which he and his associates are identified, he is receiving the appreciative recognition of fellow-craftsmen.

"They would ask, that in all the proffers of service and courtesy, the Society and its President will feel assured of hearty appreciation."

On motion of Mr. Holmes, the thanks of the Society were voted to Mr. Harry P. Nawn for courtesies extended to the members of the Society who took part in the excursion this afternoon to Section 55 of the Metropolitan sewer work.

The literary exercises of the evening consisted of an interesting description by Mr. Frank W. Hodgdon, of the surveys made for a canal from Taunton River to Boston Harbor. The talk was illustrated by a large number of maps and plans showing the location of the proposed canal and the methods used in making the surveys.

Adjourned. S. E. TINKHAM, *Secretary.*

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## Engineers' Club of St. Louis.

545TH MEETING, ST. LOUIS, MAY 21, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 P.M., with President Kinealy in the chair.

Present, twenty-two members and eight visitors.

The minutes of the 544th meeting were read and approved.

The minutes of the 321st meeting of the Executive Committee and the 7th and 8th meetings of the Governing Board were read.

The Secretary read communications from the St. Louis Chapter of the American Institute of Architects and the St. Louis Architectural Club.

The Committee on Moving submitted its final report.

The application of Mr. A. P. Greensfelder was read and referred to the Executive Committee.

The President then introduced Dr. Herman von Schrenk, who addressed the Club on "The Relation of Forestry to the Engineering Profession."

A few figures were given, showing the enormous amount of timber used in the country. The gradual exhaustion of several of the most useful varieties of timber, and the consequent increase in their price, has brought about experiments and investigations to secure substitutes. This is especially the case in the northeastern part of the United States. A case was cited of one railroad which no longer buys white oak ties, but imports ties of another variety from Canada.

The replanting of denuded areas, the rational cutting of timber in present forests and the treating of timber to increase its life are methods for preventing the exhaustion of the supply of timber. The steps being taken in eastern states to replant trees were described, some of the states making

annual appropriations for that purpose. Trees are also being planted on barren areas in western states. One large railroad system had recently been induced to cut the timber for ties from a large area in accordance with the principles of forestry and under the direction of the Bureau of Forestry. The rational cutting of timber means the cutting only of those trees which have reached their prime, *i.e.*, which would not increase in value if allowed to stand. The rotting of timber requires the presence of both air and moisture. Timber when completely submerged in fresh water is preserved in its original strength for ages. Specimens were also shown of timber which had been exposed to the air in dry localities and which appeared to be perfectly preserved. Railroad ties, telephone and telegraph poles and the timber in docks, flumes and paving blocks were given as examples in which rotting occurred at high rates. An outline of the methods of treating timber to prevent rotting was given, and specimens of the treated timber were shown. One specimen was a section of a tie from an European railroad and had been in service thirty years. It appeared to be serviceable for an additional thirty years.

The work of the Bureau of Forestry was outlined. A number of examples were given of its successful efforts in securing the co-operation of large corporations in extensive experiments. The speaker urged the co-operation of all engineers in the work of the Bureau of Forestry and stated that great assistance could be given by calling the attention of the bureau to unusual cases in the decay of timber.

In the prolonged discussion which followed, Messrs. Klauder, McAdam, R. D. O. Johnson, R. H. Phillips, Van Ornum, Chaphe, Hiram Phillips and others participated.

The President announced that at the meeting on June 4th Mr. R. H. Tait would address the Club on the subject, "Mechanical Refrigeration."

The meeting then adjourned to an adjoining room, where a light lunch was served.

D. W. Roper, *Secretary.*

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546th Meeting, St. Louis, June 4, 1902.—Held at the rooms of the Club, 709 Pine street, at 8 p.m., with Vice-President Van Ornum in the chair. Present, twenty-three members and six visitors.

The minutes of the 545th meeting were read and approved.

The application of Mr. E. J. Boehmer was read and referred to the Executive Committee.

The Secretary read a communication, dated May 26, 1902, from Mr. J. A. Parker, Secretary of the Empire Realty Co., and also a copy of a reply which had been signed by the President and Secretary of the Engineers' Club, the Architectural Club and the St. Louis Chapter of the A. I. A. The Secretary then took the chair, and Mr. Van Ornum, as a member of the Governing Board, related the events leading up to the correspondence.

Upon assuming the chair, Mr. Van Ornum introduced Mr. R. H. Tait, who read a paper entitled "Mechanical Refrigeration."

Early attempts at refrigeration were described. The first storage house was built in 1858 and used ice as the refrigerant. The scheme included a drying device and a ventilating fan similar to those used to-day. Some years later the method was greatly improved by the use of a mixture of salt and ice, which produced a much lower temperature.

Refrigerating machines were built as early as 1775. These early machines all used rapid evaporation as the means for producing cold temperatures. The first compression machine was built in 1834 and used ether as the refrigerating medium. The system most largely used to-day is the "ammonia compression" system. Ice-making and refrigerating machines are now made of any desired capacity. The cost of a plant, exclusive of buildings, will range from $2500 per ton for a plant making one ton of ice per day to about $500 per ton for a hundred-ton plant. The cost of production will be about $4.50 per ton for a one-ton plant and about 60 cents to 70 cents for a hundred-ton plant.

The distribution of refrigeration from a central station is a comparatively new art, but has passed the experimental stage. The first pipe-line system was laid in Denver in 1899 and the second in St. Louis in 1900. The methods of construction of the pipe line, of making connections to customers and the details of operation were described. The service supplied ranges from a single beer faucet in a saloon to large cooling chambers in the packing houses.

The present pipe line in St. Louis includes about 12,000 feet of mains and 5000 feet of laterals. An additional 11,000 feet of mains now under construction will make the St. Louis refrigerating pipe line the largest in the world.

In the discussion which followed, Messrs. Klauder, Humphrey, Ashton, Trepp, Bary, Russell and others participated.

The meeting then adjourned to the adjoining room to partake of a lunch provided by the Entertainment Committee.

D. W. Roper, *Secretary.*

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## Montana Society of Engineers.

A regular meeting of the Montana Society of Engineers was held May 10, 1902, at Room 14, Tuttle Block, Butte, Mont., with eleven members present; President Harper in the chair.

The minutes of the last meeting were read and approved.

The final report of the Annual Meeting Committee was presented by Mr. Goodale, and on motion the report was accepted and the committee discharged.

Moved that the Secretary be instructed to tender a vote of thanks to the Anaconda Copper Mining Company for the courtesies extended to the Society at its annual meeting. Motion carried.

Moved that the Society adjourn, for its summer vacation, until the first regular meeting in September, subject to the call of the President. Motion carried.

The discussion of the interoceanic canals was opened by Mr. C. H. Moore, who took the Panama Canal for his subject, and gave a very interesting history of the same. Mr. Pearce, who had recently crossed the Panama Railway, gave a very instructive account of the present condition of the work on the canal.

Society adjourned. Richard R. Vail, *Secretary.*

## Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, Cal., June 6, 1902.—Called to order at 8.30 p.m., by Past President George W. Dickie.

The minutes of the last regular meeting were read and approved.

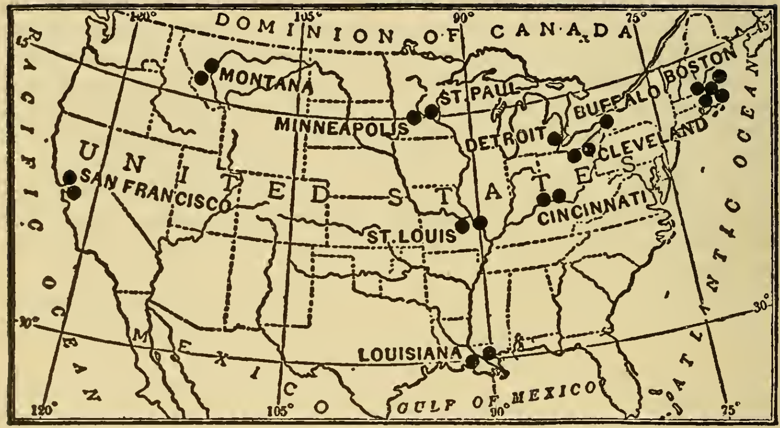
A paper was read by the Secretary, submitted by Mr. John Richards, on the subject of "Rotative Pumping," which was discussed at length by Mr. Byron Jackson and others.

It was moved by Mr. Grunsky that the Secretary confer with the Association of Engineering Societies and obtain from its Secretary the probable expense of having a certain number of advance copies of Mr. Richards' paper printed and circulated to the members for the purpose of inviting written discussion, and that the Secretary have power to proceed under a reasonable expenditure; and that the subject be brought up again at the next meeting for fuller discussion. This motion was carried.

Mr. Grunsky, for Mr. Connick, explained the status of the proposed engineers' convention, stating that, for reasons fully set forth in the circular sent to the members, it had become necessary to postpone the convention until autumn. Permission had been given the Society to visit the military fortification works at Fort Point and the United States Navy Yard at Mare Island, and, as these invitations would hold good for some time to come, there would not be any loss of advantage for reason of postponing the convention.

Mr. Molera moved that the report be received, that the committee be discharged and that the expenses incurred for printing, postage and incidentals be paid out of the treasury of the Technical Society. Motion was carried.

Meeting thereupon adjourned. Otto von Geldern, *Secretary.*


DOMINION OF CANADA
MONTANA
ST PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
UNITED STATES
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
30°
45°

# LISTS OF MEMBERS

OF THE SOCIETIES COMPOSING THE

# Association of Engineering Societies.

DECEMBER 31, 1901.

# Lists of Members of the Associated Societies.

Abbreviations for designating membership:

| | |
|---|---|
| MEM | FOR MEMBER. |
| HON. MEM | FOR HONORARY MEMBER. |
| ACT. MEM | FOR ACTIVE MEMBER. |
| ASSOC. MEM | FOR ASSOCIATE MEMBER. |
| COR. MEM | FOR CORRESPONDING MEMBER. |
| JUN. MEM | FOR JUNIOR MEMBER. |
| ASSOC | FOR ASSOCIATE. |
| JUN | FOR JUNIOR. |

## Boston Society of Civil Engineers.

ADAMS, EDWARD P., Mem.,
Landscape Architect and Civil Engineer,
53 State street, Room 1104, Boston, Mass.

ADAMS, HENRY S., Mem.,
Civil Engineer, 53 State street, Room 542, Boston, Mass.

ADDICKS, WALTER R., Mem.,
Chief Engineer, Boston, Bay State, Roxbury and South Boston Gas Companies, 24 West street, Boston, Mass.

AIKEN, CHARLES W., Mem.,
Consulting and Contracting Engineer,
82 Washington street, New York, N. Y.

AIKEN, ROY C., Mem.,
Civil Engineer, cor. Atlantic and Prospect streets, Atlantic, Mass.

ALLARD, THOMAS T., Mem.,
Civil Engineer, Fort Caswell, N. C.

ALLEN, C. FRANK, Mem.,
Professor of Railroad Engineering, Mass. Inst. of Technology,
Boston, Mass.

ALLEN, CHARLES A., Mem.,
Consulting Engineer, 44 Front street, Worcester, Mass.

ANDREWS, DAVID H., Mem.,
President, Boston Bridge Works, 70 Kilby street, Boston, Mass.

ARMSTRONG, SAMUEL G., Mem.,
Civil Engineer,
Kimberley Villa, Harrington street, Cape Town, South Africa.

ASPINWALL, THOMAS, Mem.,
Aspinwall & Lincoln, Civil Engineers,
120 Tremont street, Room 606, Boston, Mass.

ATWOOD, JOSHUA, 3d, Mem.,
Chief Engineer, Paving Division, Street Department, Boston.
Residence, 158 Foster street, Brighton, Boston, Mass.

Atwood, Thomas C., Mem.,
Assistant Engineer, 710 City Hall, Philadelphia, Pa.
Badger, Frank S., Mem.,
Civil Engineer, Bristol, Vt.
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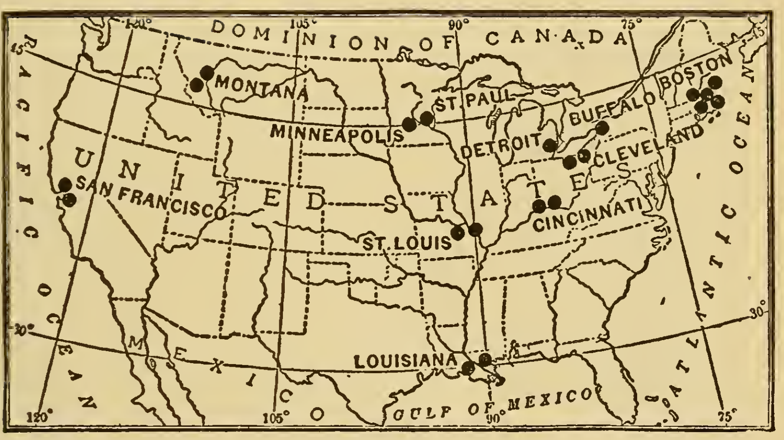
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90°
75°
45°
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